DOCUMENTS EXPEDITING PROJECT

83d Congress
1st Session

COMMITTEE PRINT

EFFECT OF BATTERY ADDITIVE AD–X2 ON LEAD ACID BATTERIES

REPORT

OF THE

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

SUBMITTED TO THE

SELECT COMMITTEE ON SMALL BUSINESS
UNITED STATES SENATE

APRIL 6, 1953

Printed for the use of the Select Committee on Small Business

---

UNITED STATES
GOVERNMENT PRINTING OFFICE
31745 WASHINGTON : 1953

SELECT COMMITTEE ON SMALL BUSINESS

EIGHTY-THIRD CONGRESS

(Created pursuant to S. Res. 58, 81st Cong.)

EDWARD J. THYE, Minnesota, *Chairman*

CHARLES W. TOBEY, New Hampshire	JOHN SPARKMAN, Alabama
HOMER FERGUSON, Michigan	RUSSELL B. LONG, Louisiana
LEVERETT SALTONSTALL, Massachusetts	GUY M. GILLETTE, Iowa
ROBERT C. HENDRICKSON, New Jersey	HUBERT H. HUMPHREY, Minnesota
ANDREW F. SCHOEPPEL, Kansas	LESTER C. HUNT, Wyoming
JAMES H. DUFF, Pennsylvania	GEORGE A. SMATHERS, Florida

LAURANCE G. HENDERSON, *Staff Director*
WALTER B. STULTS, *Assistant Staff Director*
BLAKE O'CONNOR, *Professional Staff Member*
MINNA L. RUPPERT, *Chief Clerk*

DOCUMENTS EXPEDITING PROJECT

LETTER OF TRANSMITTAL

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
OFFICE OF THE PROVOST,
Cambridge, Mass., December 16, 1952.

HON. JOHN SPARKMAN,
Chairman, Select Committee on Small Business,
United States Senate, Washington 25, D. C.

DEAR SENATOR SPARKMAN: This airmail letter is to advise you that we have this day transmitted two copies of the report prepared by Professor Harold C. Weber concerning the effect of Battery Additive AD–X2 on lead acid batteries. Following your suggestion we have entrusted these reports to Mr. Goodwin who will deliver them personally to you in Washington.

There are certain points concerning these tests which I should like to emphasize.

We are making the results of the tests available solely to the Select Committee on Small Business. M. I. T. will make no public statement in connection with this investigation.

As you know, this work was undertaken by M. I. T. upon the request of your committee and, while we were reluctant to become involved in a controversial issue, we felt that we should make our facilities available to you in the public interest. All expenses in connection with these tests were covered by M. I. T. The M. I. T. staff members who worked on the tests received no compensation from any source, and they have no financial or consulting interest in the product tested or in other similar products.

I would point out further that there are no recommendations included in the report, nor did our group arrive at any definitive conclusions with respect to the commercial value of the product. The report sets forth the results of very careful laboratory tests, and these results have been corroborated and analyzed statistically.

Four copies of the report have been prepared, two of which are being sent to you and the other two will remain here at M. I. T.

Professor Weber has gone to great pains and a considerable personal sacrifice in time to conduct a thorough, competent, and completely nonpartisan investigation of the effects of product AD–X2 on lead acid battery cells. We hope that the report will contribute to the important work of your committee.

Very sincerely yours,

J. A. STRATTON,
Vice President and Provost.

CONTENTS

	Page
1. Authority	1
2. Scope of Investigation	1
3. Supporting Scientific Authority	1
4. Recommendations	1
5. Summary of Results	2
6. Discussion of Results	2
7. Experimental Procedure	10
8. Statistical Analysis of Results by Prof. G. P. Wadsworth and Dr. J. G. Bryan	14
9. Statement of Supporting Scientific Authority by Prof. James A. Beattie	24
Appendix: Supporting Laboratory Data	26

SOME FACTS CONCERNING THE EFFECT OF BATTERY ADDITIVE AD–X2 ON LEAD ACID BATTERIES

1. Authority

The work covered by this report was undertaken at the request of the Select Committee on Small Business of the United States Senate, to render a public service through this Committee.

In a desire to employ its facilities as fully as possible in the public interest, and at the request of the Select Committee on Small Business of the United States Senate, the Massachusetts Institute of Technology made available laboratory services and facilities for carrying out tests.

2. Scope of Investigation

This investigation concerns some of the effects noted when Battery Additive AD–X2 was added to lead acid storage batteries. The finding of facts was considered of more importance at this time than the development of any theory to explain the facts. Theoretical discussion will be pursued only as far as is deemed necessary for the proper presentation of the facts reported. This viewpoint is not to be interpreted as indicating that a theory for the action of this and possibly other similar battery additives has not been developed.

A complete investigation would have required extensive laboratory and field experimentation. Because of the limited time available, a laboratory procedure based on tests which could be performed rapidly was developed. This test method did show several differences between cells treated with AD–X2 as compared with untreated cells.

3. Supporting Scientific Authority

In view of the widespread feeling that battery additives—particularly those composed largely of mixtures of magnesium and sodium sulphate—have no beneficial action on batteries, it was thought advisable to obtain supporting scientific confirmation for the facts found. Through the office of the President of the Massachusetts Institute of Technology, Prof. James A. Beattie of the Chemistry Department was asked to observe the experiments and to verify independently the facts established. Prof. Beattie observed a portion of the experimental work, and, in the limited amount of time he had available, did verify most of the facts tabulated in the next section.

Through the same authority, Prof. G. P. Wadsworth and Dr. J. G. Bryan were requested to analyze the results statistically.

4. Recommendations

None, since the purpose of this work was to establish facts.

Definitions

In this report, the word "cell" will be used to designate a single unit consisting of a set of positive and negative plates, together with the container in which they are held. The word "battery" will be used

to designate any group of cells which has been subjected to the same treatment. Cells in any one battery should be comparable, one with the other. Comparisons between batteries are undesirable; rather comparisons should be limited to the different cells in any particular battery.

5. Summary of Results

For the cells tested:

(*a*) Among the cells in any chosen batter, all cells in such battery having been subjected to the same previous history, except for treatment with AD–X2, treated cells showed larger capacities than did untreated cells, both being subjected to the same conditions of discharge.

(*b*) When AD–X2 was added to cells containing sediment, the amount of sediment decreased both while the battery was on charge and when it was not on charge.

(*c*) Cells treated with AD–X2 when on charge presented a markedly different appearance from those on charge without treatment. The gas evolved in the treated cells was in the form of minute bubbles, while that evolved in the untreated cells was in bubbles estimated to be 4 to 10 times as large as those evolved in the treated. The liquid surface in the treated cells presented a different appearance from that in the untreated cells.

(*d*) The surface of a negative plate in a treated cell was distinctly softer than the surface of a similar plate in an untreated cell, both having been subjected to the same charge conditions. Often, softening was first evident near the edges of the negative plate.

(*e*) Under similar charge conditions, treated cells lost less liquid than untreated cells.

(*f*) Under identical conditions of charge, treated cells operated 2 to 5 degrees Fahrenheit cooler than did untreated cells.

(*g*) During charge, and starting with discharged cells, treated cells gave higher hydrometric readings than did untreated cells, the differences being greater than could be explained on the basis of the treating material added.

(*h*) When AD–X2 was added to a cell containing a diluted electrolyte, as in a discharged cell, the conductivity of the electrolyte increased.

6. Discussion of Results

In this section, each of the eight facts presented under "Summary of Results" will be supported by the laboratory data collected during the tests performed. All of the data in this section have been taken from the more complete data presented in the Appendix. Comments to aid in understanding and interpreting these supporting data, here presented, will be added when it is believed these will be helpful.

(*a*) Among the cells in any chosen battery, all cells in such battery having been subjected to the same previous history, except for treatment with AD–X2, treated cells showed larger capacities than did untreated cells, both being subjected to the same conditions of discharge.

Laboratory data in support of this fact are given in Table I.

For clarity, certain expressions used in this tabulation are defined at this point.

Preliminary selection test means that the cell was charged for a short period at a low rate, and then discharged at a low rate, in an attempt to learn something of the condition of this cell relative to the others in the same battery before any cells were treated.

First discharge means that the cell, following the preliminary selection test, was given a short charge, either with or without AD–X2 added, as indicated in the table, and then subjected to a rather heavy discharge.

First recovery means that the cell was subjected to an additional discharge after having undergone a discharge and after having been allowed a rest period, but without having received any additional charge.

Second recovery means that the cell was subjected, after a second rest period, to a second discharge without having received any additional charge.

Second discharge means that the cell, irrespective of its previous treatment, had received a second charge and had then been subjected to a second discharge.

Third discharge means that the cell, irrespective of its previous treatment, had received a third charge and had then been subjected to a third discharge.

In the following tabulation, numbers following the phrases defined on the preceding page refer to the minutes duration of the test being tabulated. Cells marked with an asterisk have been treated with AD–X2. It is to be remembered that, in evaluating the various cells, only cells in the same battery are to be specifically compared. Variation from battery to battery, irrespective of the test treatment received, is believed too great to warrant interbattery comparison.

Table I

Cell No.		2*	3
First Discharge	36½	33	26
First Recovery	22	26½	19
Second Discharge	44½	46½	38½

Reference to the Appendix will show that Cells 1 and 3 have an unfair advantage, since on the first attempt to charge these three cells, Cell 2 developed an internal short circuit which was found after 9 hours and 10 minutes of charging, during which time sulphate was being eliminated in Cells 1 and 3, but not in Cell 2. Moreover, during Second Discharge the connecting lug broke on Cell 2 making necessary a makeshift connection which could have shortened the time of Second Discharge for Cell 2. In spite of these two adverse effects, Cell 2 still tests better than Cells 1 or 3.

Cell No.	4	5*
First Discharge	6 min.	55 min.
First Recovery	0	24 min.
Second Recovery	0	14 min.
Second Discharge	5½ min.	80¾ min.
	AD–X2 now added to Cell 4 and charged for 58 min. at 7 amp.	
Third Discharge	8¼ min.	

When Cell 4 was discharged after 58 min. at 7 amp. without AD–X2, it could be discharged at 5 amp. for 5½ min. When AD–X2 was added and same cell charged for 58 min. at 7 amps., it could be discharged at 5 amp. for 8¼ minutes, even though 58 minutes is too short a charge time to get the full effect of AD–X2,

according to the manufacturer. There are two effects to be noted: (1) After treatment, Cell 4 is recovering at a faster rate than it was before treatment. (2) Even though Cell 4 made a very poor showing against treated Cell 5, it seems probable that eventually Cell 4 will become as good as Cell 5, indicating that Cell 4 is suffering from chemical, rather than mechanical deterioration.

Cell No.	6	7*
First discharge	8 min.	15 min.
Second Discharge	20 min.	30 min.
First Recovery	2 min.	12 min.
Second Recovery	DEAD	7 min.
Third Discharge	4⅓ min.	55¼ min.

Cell No.	8	9	10*
	Battery was discharged and allowed to stand.		
First Recovery	DEAD	17¾ min.	17¾ min.

This was a new unused low-priced automobile battery. Treated cell shows no advantage over untreated, as would be expected in a new battery. Even though new, one cell of this battery, Cell 8, had a partial internal short, as indicated by its going dead on standing.

It is unusual to find two cells, even in the same battery, as close in test characteristics as are Cells 9 and 10.

Cell No.	11*	12*	13	14
	By selection test, Cell 11 was worst cell; Cells 12-13-14 about equal condition. Battery charged and then cells discharged to 1 amp. on short circuit.			
First Recovery	21 min. 15 sec.	27 min. 45 sec.	20 min. 30 sec.	19 min. 45 sec.
Second Recovery	24 min.	26 min. 45 sec.	17 min. 48 sec.	23 min. 48 sec.

Cell No.	15*	16
	By selection test, Cell 15 was poorer.	
First Discharge	9 min. 30 sec.	10 min. 20 sec.
Second Discharge	11 min.	10 min. 30 sec.
Third Discharge	47 min.	45 min. 50 sec.
Fourth Discharge	21 min.	24 min. 10 sec.

Cell No.	17	18	19	20*	21	22*
	Treated cells were worst two cells in battery by selection test.					
First Discharge	18 min. 45 sec.	Terminal broke	37 min. 30 sec.	23 min. 45 sec.	29 min. 30 sec.	33 min.

Cell No.	23	24*	25	26*	27	28*
	All cells in this battery were dead by selection test, except Cell No. 23.					
First Discharge	25 min. 30 sec.	21 min. 15 sec.	16 min.	19 min. 15 sec.	14 min. 20 sec.	26 min. 30 sec.

Note that one treated cell is slightly better than the best cell in the battery, Cell 23 untreated, and of the other four, the two treated cells are better than the two untreated cells.

Cell No.	29	30*
	No preliminary selection test made.	
First Discharge	46 min. 30 sec.	75 min. 15 sec.

Cell No.	31*	32*	33	34
	No preliminary selection test made.			
First Discharge	14 min. 50 sec.	13 min. 45 sec.	6 min. 35 sec.	6 min. 1 sec.
Second Discharge	24 min. 15 sec.	22 min. 45 sec.	22 min. 10 sec.	18 min. 40 sec.
First Recovery	77 min. 30 sec.	Not Done	78 min. 30 sec.	Not Done

This battery was made from two large cells. The four resulting cells are of low ampere-hour capacity. These figures could indicate that because of this, the untreated cells after two periods of charging have recovered sufficiently to equal the treated cells, a result which would not be unexpected under such conditions.

Cell No.	35	36*	37	38*	39	40

All cells showed dead on preliminary selection test except Cell 37. Cells 35 and 36 found to be shorted through case. Case resistance between 36 and 37 less than 2000 ohms. Discard 35–36–37, since with 35 and 36 useless there are no cells for direct comparison with 37. Also discarded Cells 38, 39, 40, since these showed dead after treating and trying to charge. Evidently, case is shorted from cell to cell. All succeeding cells of this type will be transferred to hard rubber cases with empty pockets between cells.

Cell No.	41	42*

By selection test, both cells were dead. Cell 42 treated. Although two attempts were made to charge these cells, neither would take a charge. On second attempt, Cell 41 sulphated out and both cells were discarded.

Cell No.	43	44*
	By selection test, both cells were dead. Cell 44 treated.	
First Discharge	4 min.	12 min. 30 sec.

Cell No.	45*	46
	By selection test, both cells were dead. Cell 45 treated.	
First Discharge	DEAD	DEAD
Second Discharge	19 min. 45 sec.	9 min.

Cell No.	47*	48
	Both cells dead by selection test. Cell 47 treated.	
First Discharge	Less than 1 min.	DEAD
Second Discharge	13 min.	DEAD
Third Discharge	28 min.	5 min.

After Second Discharge, Cell 48 might have been judged mechanically defective. However, after third discharge, it must be concluded that the difficulty is chemical deterioration which is being corrected as recharging continues. Because of treatment, chemical deterioration in Cell 47 is evidently being corrected more rapidly than in untreated Cell 48.

Cell No.	49	50*
	Both cells dead, by selection test. Cell 50 treated.	
First Discharge	DEAD	DEAD
Second Discharge	7 min. 10 sec.	11 min. 45 sec.

Cell No.	51	52*
	Both cells dead by selection test. Treated Cell 52.	
First Discharge	11 min. 30 sec.	8 min. 45 sec.
Second Discharge	7 min. 15 sec.	5 min. 15 sec.

On examining cells, Cells 51 and 52, Cell 52 had four cracked positives, but 51 had none. This fact should be considered in comparing these two cells.

Cell No.	53*	54
	Both cells dead by selection test. Cell 53 treated.	
First Discharge	30 min. 30 sec.	30 sec.
Second Discharge	19 min. 50 sec.	1 min. 40 sec.
Third Discharge	4 min. 55 sec.	30 sec.
Fourth Discharge	40 min.	8 min. 25 sec.

Note that Cell 54 is evidently not mechanically defective since on repeated charge and discharge, it is recovering slowly, as would be expected. Assuming both cells originally of equal condition, note rapid recovery of Cell 53.

Cell No.	55*	56
	Both cells dead by selection test. Cell 55 treated.	
First Discharge	2 min. 5 sec.	1 min.
Second Discharge	10 sec.	20 sec.
Third Discharge	16 min. 10 sec.[1]	12 min. 15 sec.

[1] Bad connection on voltmeter on Cell 55. This Cell would have run longer.

(*b*) When AD–X2 was added to cells containing sediment, the amount of sediment decreased both while the battery was on charge and while it was not on charge.

A small glass-cased Willard thick plate cell, approximately 15 years old, had been left in an uncharged condition for several years. Well over an inch of sediment had collected in the bottom of the cell, and the liquid level had fallen over two inches below the tops of the plates. Distilled water was added to restore the level, Battery AD–X2 was added to the cell, and the unit placed on charge at 3 amperes. In several hours sediment reduction was evident, and by the time the cell was fully charged, the sediment was less than ¼ inch deep in the cell bottom. This occurred in May 1952. During the present series of tests this cell was again examined, and it was evident to those present and also present when the cell was originally charged after treatment that sediment has shown a further considerable decrease. The cell has not been recharged.

Two groups of two cells, each of heavy plate Exide batteries (two plates per cell) were observed in the summer of 1952 at the Army Base in Boston. It was said that before treatment with AD–X2 these cells contained so much sediment that it was above the bottom of the plates, and some cells were being partially shorted by the sediment. The cells were treated about January 1952. When observed in July, the sediment had receded about ½ inch below the bottoms of the plates. The cells were moved to Cambridge in September where they could be more readily observed. Sediment in one pair of cells is now approximately 1⅛ inches below the plate bottoms, while in the other pair it is about 1 inch below the plates. On November 6 at 1:30 p. m. the second pair was placed on charge at 4 amp. until 5 p. m. On succeeding days for one week this pair was alter-

nately charged and discharged. From marks placed on the glass cases, a reduction of about ⅛ inch in sediment depth has been noted, some of this occurring while the cells were sitting idle for several days after the charge-discharge cycle. Complete sediment disappearance is not expected in these cells, but the level has receded to a point where difficulty from sediment is a remote possibility.

A record is made at this time of an automobile battery in a rubber case. A hole was accidentally knocked in the side of the case by a stone thrown up from the road. Although the battery was eighteen months old and had been treated with AD–X2 six months previously, no sediment was found in the cell bottom, although some would have been expected. Incidentally, the negative plate exposed through the hole was soft and apparently in excellent condition.

(*c*) Cells treated with AD–X2 when on charge presented a markedly different appearance from those on charge without treatment. The gas evolved in the treated cells was in the form of minute bubbles, while that evolved in the untreated cells was in bubbles estimated to be 4 to 10 times as large as those evolved in the untreated. The liquid surface in the treated cells presented a different appearance from that in the untreated cells.

Differences of the type above described were noted in batteries made up of Cells 31–32–33–34, 49–50, 45–46, 53–54, 44–43, and are specifically mentioned in the Appendix.

(*d*) The surface of a negative plate in a treated cell was distinctly softer than the surface of a similar plate in an untreated cell, both having been subjected to the same charge conditions. Often softening was first evident near the edges of the negative plate.

This difference was noted in batteries made up of Cells 4–5, 6–7, 51–52, 53–54, and is specifically mentioned in the Appendix.

(*e*) Under similar charge conditions, treated cells lost less liquid than untreated cells.

This fact is substantiated by Table II. Treated cells are indicated by an asterisk.

Table II

Cell No.	31*	32*	33	34
Liquid lost cc.	None	None	22	31

These four cells were in the same battery and are inter-comparable.

Cell No.	49–50*	45*–46	53*–54	44*–43	55*–56	103A–103B*
Liquid lost cc.	38–72	20–54	20–66	18–100	68–92	122–88

Above figures obtained after charging on November 5. Although the figures for Cells 49–50 seem inconsistent with the others, they are the amounts recorded.

Cell No.	49–50*	45*–46	53*–54	44*–43	55*–56	103A–103B*
Liquid lost cc.	44–0	12–38	0–42	0–52	0–32	28–0

Above figures obtained after charging on November 6. To see how the levels would change in the above tabulated cells when these batteries were allowed to stand overnight without charging, on November 7 the liquid levels were again adjusted to the original level. The following amounts of water were required.

Cell No.	49–50*	45*–46	53*–54	44*–43	55*–56	103A–103B*
Liquid drop cc.	42–46	22–28	0–0	26–22	34–32	34–34

These figures give some credence to the belief that differences in water requirements were not due to the amount of gas caught between and under the plates. The gas referred to here is not that caught in the plate pores.

Note above cells are grouped two in a battery as indicated. Compare cells in same battery—but do not intercompare batteries.

(*f*) Under identical conditions of charge, treated cells operated 1 to 3 degrees Centigrade (1.8 to 5.4 degrees Fahrenheit) cooler than did untreated cells.

This fact is substantiated by Table III, made up of data chosen from the Appendix. Treated cells are indicated by an asterisk. As before, comparisons must be made between cells in the same battery and not between batteries.

Table III

Cell No.	4–5*	6–7*	41–42*	47*–48
Temp. °C.	33.8–29.8	27.8–28.9	38–33	32–36

Cell No.	51–52*	53*54	55*56
Temp. °C.	28–29	27–32	34–35

An interesting fact about this temperature difference is brought out by Table IV in which rather extensive temperature readings are recorded for Cells 31–32–33–34, all in the same battery.

Table IV

First Charge on Cells 31–32–33–34.

A general observation that during this charge treated cells ran about 2° C. cooler than untreated cells.

Second Charge:

Cell No.	31*	32*	33	34	Time
Temp. °C.	25	24	27	26	2:25
	26	25	28	28	2:32
	28	27	30	30	2:45
	32	31	31	30	3:32
	35	34	34	34	4:57

On charge three days later (October 31):

Cell No.	31*	32*	33	34
Temp. °C.	30. 8	30. 8	31. 6	32

Cell No.	31*	32*	33	34
Temp. °C.	33	33	34	34

From Table IV the conclusion might be drawn that the difference in temperature during charge between treated and untreated cells became smaller when both cells had been charged and discharged enough to correct chemical deterioration. It was previously pointed

out under the discussion on capacity that the untreated cells in this group appeared to have recovered sufficiently because of their small capacity and repeated charging, so that they differed but little from the treated cells. The temperatures for October 31 and November 3 as compared with those on Second Charge gives some indication of this effect. It would possibly have been desirable to have read all temperatures for the nearest tenth degree, but since only a difference was of interest and since it was anticipated offsetting effects might influence temperature readings, more precise readings were not made.

(*g*) During charge, and starting with discharged cells, treated cells gave higher hydrometric readings than untreated cells, the differences being greater than can be explained on the basis of the treating material added. Table V, based on the laboratory data, substantiates this fact. Treated cells are indicated by an asterisk.

Table V

Cell No.	17	18	19	20*	21	22*	All in one battery
Gravity	1160	1140	1175	1220	1145	1175	

Cell No.	23	24*	25	26*	27	28*	All in one battery
Gravity	1200	1235	1200	1225	1200	1200	

Taken on charge November 5:

Cell No.	49–50*	45*–46	53*–54	47*–48
Gravity	1050–1100	1110–1050	1110–1050	1140–1050

Cell No.	44*–43	55*–56	103A–103B*
Gravity	1105–1050	1080–1050	1050–1120

Taken on charge November 6:

Cell No.	49–50*	45*–46	53*–54	44*–43
Gravity	1090–1130	1175–1120	1175–1100	1150–1050

Cell No.	55*–56	103A–103B*
Gravity	1125–1100	1150–1175

The effect on gravity of adding the specified amount of the additive was determined as follows:

To 550 cc. of 1300 acid (approximately the amount required to bring liquid level to proper height in one cell of a group I passenger car battery) the specified amount of additive was added. When done in a graduate, not in the cell—this caused the gravity to rise to 1320 at room temperature.

When the specified amount of additive was added to one cell of a new Beacon 90-ampere-hour battery made by Gould National, the gravity rose from 1250 to 1260.

Cells 41 through 56 required approximately 800 cc. of electrolyte to bring liquid to proper level. One would conclude that in these

cells addition of additive would cause the gravity to rise less than the 10 points found in the case of the Beacon battery.

(*h*) When AD–X2 was added to a cell containing a diluted electrolyte, as in a discharge cell, the conductivity of the electrolyte increased.

This result is a direct consequence of adding an ionizable material to the electrolyte (such as magnesium or sodium sulphate). Provided such added material introduces no deleterious effects, it would seem that the desirability of this effect would be above criticism, and certainly the result itself could be predicted without recourse to laboratory experiments.

Twice during the laboratory experiments, this effect was noted once during the first experiments on Cells 1–2–3 when, on adding the additive while the cells were on charge, the voltage across the cell treated suddenly dropped, and the current through the whole battery rose (see Appendix).

On October 31, Cells 41 through 56, together with 6 as of that date unnumbered cells, were put on charge. With the charger available operating at its highest voltage, less than 1 ampere flowed through the cells. When additive was put in five of the cells, more than 5 amperes could be passed through the series of cells.

LIMITATIONS OF LABORATORY RESULTS

The difficulty of duplicating in the laboratory results obtained in the field is well recognized in engineering work. The laboratory evaluation of a material such as AD–X2 is further complicated by the great variation in the samples subjected to test, even though every effort be made to so select test units as to minimize such variation. Usually, an evaluation of how a product will act under field conditions can be obtained only after extensive laboratory experimentation. Even after such experimentation, it is common practice in engineering work to subject products to field tests. How a given innovation will perform under use conditions is the true test of its worth. For this reason, laboratory findings must be supplemented by field use data if a true evaluation is to be obtained.

7. Experimental Procedure

(A) SELECTION OF SAMPLE

Even new storage batteries show considerable variation, and when one realizes that the tests herein reported were made on partially deteriorated batteries, the difficulty of selecting a representative sample becomes even greater. It is relatively easy to obtain discarded batteries, but usually a discarded battery has deteriorated to such a degree, perhaps because of the development of mechanical defects due in considerable degree to chemical deterioration, that treatment with an additive would yield no beneficial effects.

A desirable sample for these tests would be made up of a series of cells, all of which had been subjected to the same past history, but none of which had developed so-called mechanical defects. Moreover, such a sample should have experienced chemical deterioration of the type usually referred to as sulphation. Unfortunately it is common practice to try to offset chemical deterioration by prolonged

charging. Without doubt, this often occurs when an automobile battery begins to deteriorate chemically. Without resorting to preparation of a specially deteriorated sample, which would require several months, the only alternative evident was to obtain new batteries, all of which had had the same past history, and all of which had stood for extended periods of time with the electrolyte in them, in a discharged condition, but had not been subjected to periodic attempts at recharging. The only cells really fulfilling these requirements were those from Nos. 41 to 56.

So that undesirable variation would not be introduced by the test procedure, the various batteries, although subjected to different conditions of charge and discharge, were so handled experimentally that all of the cells in any given battery received as far as possible the same treatment.

An additional troublesome point in the proper selection of a sample was the development of a method for finding cells having mechanical defects before the actual test procedure started, and without introducing changes in the cells because of the selection procedure. It was finally decided that a relatively short charge of 15 minutes to 1 hour at a rate of 2 to 5 amp., followed by a discharge at a moderate rate, offered the most hope for eliminating defective cells. This method did not serve too satisfactorily, since often a cell which showed no ability to store energy on the short charge-discharge cycle, on a longer test cycle, proved to be in satisfactory condition for test. However, among cells chosen as satisfactory for test, the preliminary test procedure did give a fairly good indication of the relative conditions of the various cells in any one battery.

Throughout the tests, the general tendency was not to treat with the additive those cells which showed up best in any one battery, but rather to reserve for treatment the poorer cells.

(B) PREPARATION OF THE SAMPLE FOR TEST

In most cases, the batteries to be selected for test were opened, the plates examined—particular attention being paid to cracked positive plates—and new separators were installed. Short circuits between the cells in a given battery container were checked, particularly if the container was of composition rather than hard rubber. Wherever practical, an empty cell pocket was left between treated and untreated cells to ensure that there was no leakage between the two kinds of cells, and also to serve as heat insulation to prevent temperature equalization between treated and untreated cells.

Since the cells chosen for test were sulphated, there was some question as to what electrolyte should be added to the cells. In practically every case, if the cells still contained the original electrolyte and the sulphate which would be released from the plates on complete charging, a sufficiently high gravity would be attained to meet the manufacturer's specifications. In such cases, only distilled water was added to make up the electrolyte level. Where the cells contained none of the original electrolyte, the general procedure of adding a sulphuric acid-water electrolyte of 1100 gravity was followed. Had these cells been fully charged, it is quite probable that eventually the gravity of the electrolyte would have exceeded the manufacturer's specifications, and it would have been necessary to withdraw electro-

31745—53——3

lyte and substitute distilled water. In none of the tests was charging carried far enough to make such an adjustment necessary.

(C) TEST METHODS

Charging Conditions

All cells in any given battery were charged in series to ensure that the same number of ampere hours passed through each cell in the battery. Where individual cells were not dead before charging started, they were brought to a dead condition by discharging to a point where on direct short through an ammeter less than 1 ampere was indicated on the meter, the full-scale reading being 25 amperes.

(D) DISCHARGE CONDITIONS

During discharge each cell in a given battery was discharged individually, and every attempt was made to have the discharge rate the same for each cell. No particular attempt was made to have the conditions the same in all batteries during either charge or discharge, although to a very rough approximation, conditions were comparable for most batteries tested.

(E) INSTRUMENTS

In the early experiments batteries were charged by means of a variable voltage selenium rectifier, capable of supplying up to 10 amperes at 9 volts. In later experiments a "Lemco" double unit service station charger was employed. Each unit could deliver up to 6 amperes at approximately 100 volts. Voltage was adjustable in several steps. During charging when using the "Lemco" unit, current was measured by the rather crude ammeters built into the charging unit. When using the selenium rectifier, the rate of charge was indicated by inserting a small Weston ammeter directly in the charging circuit. Discharge voltages were measured on one of two large voltmeters reading 15 volts at full scale. Readings could be made to the nearest tenth of a volt and estimated to five-hundredths of a volt. Amperage during discharge was measured on either one of two large ammeters, the full-scale reading on each being 100 units. By a series of shunts either meter could be made to read 5 amperes, 25 amperes, or 75 amperes full scale. No attempt was made to determine the absolute accuracy of the various meters used since for the tests in question relative readings were sufficient. But of those used for the discharge experiments, the two ammeters were adjusted to read the same over that part of the scale used as were also the two voltmeters.

For the measurement of gravities ordinary service station hydrometers were employed, one hydrometer being used for treated cells the other for untreated. For measuring a few gravities below 1100, a float in a graduated cylinder was used. The two hydrometers on checking were found to read the same and the additional float was found to check the two hydrometers at the 1100 point.

Temperatures were measured with ordinary laboratory thermometers, all thermometers used being checked against each other at room temperature. Only those which gave the same reading under these conditions were used.

Discharge Resistances

To control the current on discharge, variable nichrome slide wires capable of carrying 10 amperes, 50 amperes, and 100 amperes were used. Except when voltages were falling rapidly during discharge, the discharge rate could be kept constant within approximately 1/10 of an ampere without difficulty.

(F) TESTS EMPLOYED

Capacity Test

The various capacities of the cells in a chosen battery were determined by subjecting each cell in the battery after identical charge conditions to identical discharge conditions, discharge being carried to one volt in the case of each cell. The relative lengths of time to reach a potential of one volt were taken as relative measures of the amounts of energy recoverable from the cells on initial discharge.

Recovery Tests

It is well recognized that a storage battery if rapidly discharged and then allowed to stand will yield additional energy because of a recovery process which occurs. During this recovery it is assumed that either material on the interior of the plates or electrolyte not available for use in the first rapid discharge becomes available as the cell is allowed to stand on open circuit. This recovery phenomenon can be observed several times before the cell is completely discharged. The recovery tests were made in much the same way as original discharge tests and in every case as nearly as practical after the cells in any given battery had stood for the same periods of time. To this end, when two treated and two untreated cells were to be tested for recovery from the same battery, discharge, to measure recovery, was carried out with treated and untreated cells alternating in the order of tests.

Temperature Measurements

Temperatures were measured during charge by inserting thermometers directly into the electrolyte above the plates. Satisfactory temperature measurements could be made only in those instances where either a large portion or the whole cover had been removed from the cell. It was deemed impossible to remove covers from the airplane-type batteries tested without seriously injuring the batteries themselves. Therefore, no temperature measurements were made on these cells nor on some of the automobile-type batteries tested.

Liquid Loss

Liquid loss during charge was determined by first bringing all the cells to be tested to the same liquid level, the level in the case of most of the cells tested being determined by the sharp edge of the ledge cast into the container as a seat for the cell cover. After charge, liquid loss was measured by noting the number of cubic centimeters of distilled water required to once more bring the liquid level to the sharp ledge edge. This method was thought sufficiently accurate for determining the liquid loss.

(G) VISUAL OBSERVATIONS

In every case where cells under test were either in transparent containers or had had the tops removed so that the complete surface of the electrolyte was visible, marked differences in appearance were noted during the charge period between treated and untreated cells. Gas evolution from treated cells was in the form of almost pinpoint bubbles—in some cases the bubbles drifting to the surface, rather than rising, in almost cloudlike formation. These bubbles broke through the surface with very little surface disturbance, as contrasted with the much larger bubbles which rose rapidly through the untreated cells and broke through the surface with considerable spattering. The surface itself on the treated cells presented a different appearance than the electrolyte surface on the untreated. On the treated cells, this surface appeared more viscous, and in some instances almost dusty.

Repeatedly, the negative plates on treated cells were found to be considerably softer than corresponding plates on untreated cells from the same battery. Sometimes the soft areas were concentrated near the edges of the plates, and sometimes soft areas were fairly well distributed across the plate surface. The differences were readily noted by using a thumbnail as a sort of miniature plough to scoop up the softened surface. Under the same conditions, the hardened areas on an untreated negative plate could not be ploughed up.

In one of the first cells treated several months before this particular set of tests was started, well over an inch of sediment at the bottom of the glass case containing the cell disappeared, leaving behind a layer less than ⅛ of an inch thick, composed almost entirely of large flakes of sediment. A similar decrease in the amount of sediment was noted in four other glass-cased cells which were treated prior to the start of these tests. All five of these cells, however, were under constant observation throughout the tests herein reported.

(H) INCREASED CONDUCTIVITY OF DISCHARGED CELLS

It sometimes happens in a completely discharged cell that the electrolyte becomes so poor a conductor as to prevent a series of such cells from being charged on a charger of limited voltage range. Under such conditions, the addition of a material such as AD–X2 which will form a conducting solution cuts down the resistance of the cells sufficiently so that current can pass through the cells and the charging process be carried out, whereas otherwise it would be impossible, or at least require excessively long periods to build up sufficient conductivity to allow reasonable charging currents to pass. This phenomena seems to be fairly well recognized by battery workers.

8. Statistical Analysis of Results

A series of experiments to test the effect of AD–X2 on storage batteries were conducted by Prof. H. C. Weber, and after the experiments were completed, the data were submitted to us for statistical analysis. With the exceptions of relative bubble size, which was estimated visually, and softness, for which the fingernail test was

used, the data were instrument readings and therefore quantitative. Because the individual batteries could not be considered comparable one to another, treated and untreated cells from the same battery were compared, but no comparisons of instrument readings between cells from different batteries were attempted.

Restricting the analysis to within-battery comparisons does not eliminate all of the obstacles to a statistical appraisal of significance. Most statistical techniques depend upon some reasonable hypothesis as to the probability distribution of the measurements under consideration. Lacking previous experience with storage batteries, we cannot draw upon past experience as to some of the distributions involved, nor can we obtain sufficient information to estimate them from the data at hand. For this reason we have often employed nonparametric techniques to obtain estimates of significance. Since these are usually less sensitive than tests based upon specific distributions, the results would have been more impressive rather than less had parametric tests been available.

In several cases we have given more than one estimate of probability in order to compare the degrees of significance obtainable under hypotheses of varying degrees of generality.

We shall now consider the individual conclusions drawn by Professor Weber as a result of his observational data:

(*a*) "Among the cells in any chosen battery, all cells in such battery having been subjected to the same previous history, except for treatment with AD–X2, treated cells showed larger capacities than did untreated cells, both being subjected to the same conditions of discharge."

In professor Weber's data there are 11 paired comparisons which may be made on individual batteries. In some of the cases, he considered the result of one discharge and in others as many as four discharges. It is obvious from this that the amount of experimentation done on any one battery was a function of the results that he was obtaining as he progressed. This produces in all probability a set of data on nonhomogeneous situations, and also some amount of intercorrelation between the values found. For that reason we decided to use the results on the first discharge unless both or one of the batteries was "dead." In the latter event we would consider as part of the data to be analyzed the first discharge which had nonzero values for both of the cells. In table I we give the two cells which were paired and the number of the discharge for which both values were different from zero. The actual time to discharge for both the treated and the untreated cells is given, and the last column shows the difference, which is positive if the treated cells (denoted by *) stood up for a longer time.

TABLE I.—*Discharge Data*

A. PAIRS ONLY

Pair	First Registering Discharge	Time in Minutes		Difference
		Treated (*)	Untreated	
4, 5*	1	55. 00	6. 00	49. 00
6, 7*	1	15. 00	8. 00	7. 00
15*, 16	1	9. 50	10. 33	−. 83
29, 30*	1	75. 25	46. 50	28. 75
43, 44*	1	12. 50	4. 00	8. 50
45*, 46	2	19. 75	9. 00	10. 75
47*, 48	3	28. 00	5. 00	23. 00
49, 50*	2	11. 75	7. 17	4. 58
51, 52*	1	8. 75	11. 50	−2. 75
53*, 54	1	30. 50	0. 50	30. 00
55*, 56	1	2. 08	1. 00	1. 08

B. MULTIPLE CELLS

Cells	First Registering Discharge	Average Time in Minutes		Difference
		Treated (*)	Untreated	
1, 2*, 3	1	33. 00	31. 25	1. 75
17, 19, 20*, 21, 22*	1	28. 37	28. 58	−. 21
23, 24*, 25, 26*, 27, 28*	1	22. 33	18. 61	3. 72
31*, 32*, 33, 34	1	14. 29	6. 30	7. 99

Since the basic concept of significance testing is fairly simple, we shall review the general ideas before proceeding further. As soon as it is admitted that experimental results of a certain type need not all be in the same direction or constant in magnitude, there arises at once the question as to whether a particular set of observations reflect anything more substantial than drawing lots. If it can be shown that the probability of getting results of a given kind at random is not more than 1 in 20, statisticians say that the outcome is statistically significant, and if the probability is not more than 1 in 100, they say the outcome is highly significant.

To estimate the probability of getting a certain kind of result by chance, statisticians try to formulate a mathematical situation on a par with drawing lots. Of the possible tests of significance which can be applied to experimental data without presupposing knowledge of the distributions involved, we have chosen two, which are conceptually simple. In both tests, the lot-drawing hypothesis would have it that treatment with AD–X2 has no beneficial effect on battery performance, and that the asterisks might just as well have been assigned without reference to treatment. In these tests, as well as others to be described later on, we compute the probability of obtaining results this favorable or more favorable to the use of AD–X2 if the asterisks were no more pertinent to the outcome than flipping a coin.

In the first test we ask the question: "If the asterisk were nothing more than an arbitrary label assigned at random to one cell in each battery (implying that the observed differences of discharge time were due to chance alone), what is the probability that we shall observe at least as many as 9 positive differences?" In other words, what is the probability of obtaining 9, 10, or 11 positive differences in a random draw of 11 pairs? The answer is that the probability is only about .03. That is, we should expect results this favorable (9 positive differences) or more so (10 or 11 positive differences) about 3 times in 100 similar experiments.

The second test of significance is nonparametric also but involves the use of the magnitude of the numbers involved. Once again the asterisks are assigned at random for the two cells within each battery. In this case all possible sums for the differences between the treated and untreated cells are computed for every conceivable arrangement of asterisk and nonasterisk in the 11 pairs. The number of ways that a sum of the total differences for the 11 pairs can be as great as or greater than the one observed is then compared to the total number of possible sums. The ratio of these two numbers represents the probability of the occurrence of the event. In our case there are 6 ways that we can rearrange the asterisk and the nonasterisk cells in order to obtain a sum which is as great as or greater than the one observed. The total number of possible sums is 2,048, and therefore the probability P of obtaining a total sum for the 11 differences at least as great as was observed is P=.003 approximately, which is, of course, 3 chances out of 1,000. To facilitate the verification of our computations, we have presented the details in Table II and Exhibit I, which will be found at the close of this section.

This method explained in the previous paragraph seems to us to be the one which is less subject to criticism as far as the choice of data is concerned and seems to represent most fairly the probability involved. We do not feel that any estimates can be made of the actual superiority of the treated cells over the untreated cells percentagewise or in actual magnitude, because of our lack of knowledge as to the distribution of potential observations or inherent variability between cells within a battery and between batteries in the condition for which this treatment might be effective. However, since this analysis does indicate that it is very unlikely that differences such as were observed occurred by chance, it is reasonable to suppose that there must have been a favorable effect from the AD–X2. Whether or not this effect is great enough to be of commercial value is something that must be determined from field experiments both as to the percentage of batteries which are appreciably improved and as to the magnitude of that improvement.

Although we feel that the following analyses are not as justified as the preceding one, we give them here for anyone who might be interested. If only those 8 pairs which yielded a reading other than zero on the first discharge are considered as the entire legitimate evidence, then a probability of obtaining 6 positive and 2 negative signs, assuming the asterisk and the nonasterisk are distributed at random, is P=.144. We can also, of course, proceed as was done in the beforementioned analysis and calculate the probability of obtaining a sum as great as or greater than the one actually observed, assuming that the asterisks were distributed at random inside the batteries. Here the probability is P=.023. To us, this procedure does not seem to be fair, inasmuch as other experiments are available which involve the first discharge only, but they involve 3, 4, 5, and 6 cells respectively for individual batteries. It would then seem logical to utilize all of the first discharges by averaging the asterisk cells and the nonasterisk cells in each battery and subtracting one average from another if they were merely paired measurements similar to the previous data. This introduces a degree of nonhomogeneity into the data itself, but it is the best that can be done with information on the first discharge, if we are going to restrict ourselves to that. The probabilities for

the sign test are P=.073 assuming that the 8 pairs available on the first discharge and the 4 remaining comparisons available from batteries with more than two cells tested are combined in one sample. We can also apply the test of magnitude and find that the probability there is P=.005.

It is of interest to note further that if all the data were combined (that is the original 11 pairs, as given in Table I, plus the data on 4 batteries where more than two cells are tested) the respective probabilities are P=.018 in the case of the sign test and P=.0006 in the case of the magnitude test. These additional probabilities merely corroborate what we considered to be the preferred analysis.

TABLE II.—*Listing of Differences in Order of Magnitude*

Discharge 1		Discharge 2 or 3
Pairs	Multiple Cells	Pairs only
	−. 21	
−. 83		
1. 08		
	1. 75	
−2. 75		
	3. 72	
		4. 58
7. 00		
	7. 99	
8. 50		
		10. 75
		23. 00
28. 75		
30. 00		
49. 00		

EXHIBIT I.—COMPUTATION OF PROBABILITIES

First Discharge

Pairs Only (Negative Total= −3.58)

1. MAGNITUDE TEST

Better	All signs+	1 Way
Better	One Sign−	3 Ways
Better or Same	Two signs−	2 Ways
	Total	6 Ways

$$\text{Probability}=\frac{6}{2^8}=\frac{3}{2^7}=\frac{3}{128}=.023$$

2. SIGN TEST

Better	All signs+	1 Way
Better	One sign−	8 Ways
Same	Two signs−	28 Ways
	Total	37 Ways

$$\text{Probability}=\frac{37}{2^8}=\frac{37}{256}=.144$$

First Discharge—Continued

Pairs and Multiple Cells (Negative Total=3.79)

1. MAGNITUDE TEST

Better	All signs+	1 Way
Better	One sign−	6 Ways
Better	Two signs−	8 Ways (4+3+1)
Better or Same	Three signs−	5 Ways (3+1+1)
	Total	20 Ways

$$\text{Probability}=\frac{20}{2^{12}}=\frac{20}{4096}=.0049$$

2. SIGN TEST

Better	All Signs+	1 Way
Better	One Sign−	12 Ways
Better	Two Signs−	66 Ways
Same	Three Signs−	220 Ways
	Total	299 Ways

$$\text{Probability}=\frac{299}{2^{12}}=\frac{299}{4096}=.0730$$

First Registering Discharge

Pairs Only

1. MAGNITUDE TEST (NEGATIVE TOTAL=−3.58)

Better	All Signs+	1 Way
Better	One Sign−	3 Ways
Better or Same	Two Signs−	2 Ways
	Total	6 Ways

$$\text{Probability}=\frac{6}{2^{11}}=\frac{3}{2^{10}}=\frac{3}{1024}=.0029$$

2. SIGN TEST

Better	All Signs+	1 Way
Better	One Sign−	11 Ways
Same	Two Signs−	55 Ways
	Total	67 Ways

$$\text{Probability}=\frac{67}{2^{11}}=\frac{67}{2048}=.032$$

Pairs and Multiple Cells (Negative Total=−3.79)

1. MAGNITUDE TEST

Better	All Sign+	1 Way
Better	One Sign−	6 Ways
Better	Two Signs−	8 Ways (4+3+1)
Better or same	Three Signs−	5 Ways (3+1+1)
	Total	20 Ways

$$\text{Probability}=\frac{20}{2^{15}}=\frac{20}{32768}=.0006$$

First Registering Discharge—Continued

2. SIGN TEST

Better	All Signs+	1 Way
Better	One Sign−	15 Ways
Better	Two Signs−	105 Ways
Same	Three Signs−	455 Ways
	Total	576 Ways

$$\text{Probability}=\frac{576}{2^{15}}=\frac{576}{32768}=.0176$$

NOTE.—No allowance was made for fact that treated cell 52 was found to have four cracked positives nor for fact that the poorer cells were chosen for treatment.

(*b*) "When AD–X2 was added to cells containing sediment, the amount of sediment decreased both while the battery was on charge and when it was not on charge."

Although the empirical evidence supports this statement, we cannot perform a statistical test on these data.

(*c*) "Cells treated with AD–X2 when on charge presented a markedly different appearance from those on charge without treatment. The gas evolved in the treated cells was in the form of minute bubbles, while that evolved in the untreated cells was in bubbles estimated to be 4 to 10 times as large as those evolved in the treated. The liquid surface in the treated cells presented a different appearance from that in the untreated cells."

As evidence of this statement results on the following cells are given in the Appendix: 31*, 32*, 33, 34, 43, 44*, 45*, 46, 49, 50*, 53*, 54, 55*, 56, 103A, 103B*. This gave a total of 16 observations, eight on the treated cells and eight on the untreated. However, 53* and 54, could not be observed internally because of the casing, and therefore this leaves 14 available observations for analysis. Since it is reasonable to assume that previous history in the form of length of time of charge, number of discharges, etc., are not pertinent here, we have used the ordinary 2x2 contingency table with the exact probability of the arrangement computed.

	Treated	Untreated	Total
Small Bubbles	7	0	7
Large Bubbles	0	7	7
Total	7	7	14

The exact probability of the occurrence by chance of the above arrangement with the given marginal totals can be computed as follows:

$$P=\frac{7!\ 7!\ 7!\ 7!}{7!\ 0!\ 7!\ 0!\ 14!}=\frac{1}{3432}=.00029$$

Since this probability is extremely small, there is no doubt that there is considerable association between the small bubbles and the treated cells.

(*d*) "The surface of a negative plate in a treated cell was distinctly softer than the surface of a similar plate in an untreated cell, both having been subjected to the same charge conditions. Often, softening was first evident near the edges of the negative plate."

As evidence of this statement results of the following cells are given in the Appendix: 4, 5*, 6, 7*, 51, 52*, 53*, 54. All of the cells that were treated showed that the sulphate was 'soft' while in the case of the untreated cells the sulphate was hard and therefore the ordinary 2 x 2 contingency table used in (*c*) should also be appropriate as follows:

	Treated	Untreated	Total
Hard	0	4	4
Soft	4	0	4
Total	4	4	8

$$P=\frac{(4!)\ (4!)\ (4!)\ (4!)}{8!\ 0!\ 4!\ 4!\ 0!}=\frac{1}{70}$$

Although this probability is somewhat larger than that in (*c*) due to the fact that a smaller number of observations were available for analysis, there exists a significant association between the soft plates and the treated cells. However, one can certainly not conclude from this small amount of data that the treatment will always produce a plate which is softer than one not treated in the same battery.

(*e*) "Under similar charge conditions, treated cells lost less liquid than untreated cells."

The following data are presented by Professor Weber to corroborate the above statement, and the differences in Table III are the treated cell liquid loss minus the untreated:

TABLE III.—*Liquid Loss*

Pair	Nov. 5 Difference	Nov. 6 Difference
43, 44*	82	52
45*, 46	34	26
49, 50*	−34	44
53*, 54	46	42
55*, 56	24	32
103A, 103B*	34	28

A conclusion on this set of data is not particularly obvious. It would seem that the duplicate run from November 5th to November 6th would not materially increase the information since a cell which is losing water on one day would probably lose it the next with about the same order of magnitude. The difference between 50* and 49 on November 5th is negative, and Professor Weber believes that this is an interchange of the two values in writing them in his notebook. This would seem a logical conclusion, inasmuch as the loss of water in these two cells should be in the same direction on the second day, irrespective of whether or not the AD–X2 was effective. If we consider the sign test alone on November 5th, the probability of obtaining five or more positive differences, assuming the asterisk were assigned at random, would be $P=\frac{7}{64}$, and the magnitude test would yield about the same result, namely, a probability of $P=\frac{5}{64}$, since there are three 34's all of which can bear the negative sign without increasing the sum. Neither of these probabilities can be considered as significant. If November 6 were considered the data on which the conclusions were to be drawn, the probability of both the sign and the magnitude test is $P=\frac{3}{64}$, which would reverse the decision. Neither of these

techniques, of course, takes into account the possible distribution of the measurements. Since a measurement in the difference of level in the liquid is much more likely to be distributed in a manner for which ordinary statistical techniques would apply such as testing the hypothesis that the mean difference is greater than zero, we have computed the variation of the mean difference from zero in terms of the standard error of this difference on the basis that the mean difference normally distributed. This is commonly known as the "t" test, and in our case it is that statistic based on five degrees of freedom. The value of t for November 5th is t=2.01, and utilizing a one-sided hypothesis the probability is P=.051, which is on the borderline of significance. On November 6th, t=8.92, the probability of which is very much smaller than one in a thousand and thus is highly significant. Unfortunately, these two estimates cannot be combined because the amount of dependence cannot be reliably estimated. It would appear to us that more independent data should be obtained if there is doubt as to the —34. On the other hand, the very significant result obtained on November 6th lends credence to Professor Weber's belief that he made a clerical error in recording the difference between 49 and 50* on November 5th.

(*f*) "Under identical conditions of charge, treated cells operated 2 to 5 degrees Fahrenheit cooler than untreated cells."

Referring to Table IV of Professor Weber's text, it seems fair to assume that the operating temperature difference is a function of time, and that both treated and untreated cells will eventually approach the same temperature. This fact contrasts with the conditions of the previous conclusions, which did not seem to be systematically dependent upon time. There is not enough data to enable us to make a reliable estimate of the temperature difference as a function of time, and for this reason we do not believe that a statistical test based on the magnitude of the difference would be legitimate. This forces us to confine our analysis to the sign test, which, of course, is not very sensitive; and because of its insensitivity, we can fail to establish the significance of an effect which actually exists. Relevant data are shown in our Table IV below:

TABLE IV.—*Temperature Differences*

Pair	Difference
4, 5*	4
6, 7*	−1
41, 42*	5
47*, 48	4
51, 52*	−1
53*, 54	5
55*, 56	1

The differences recorded in Table IV were obtained by subtracting the temperature of the treated cell from the temperature of the untreated cell. In seven pairs the difference was positive five times, and by the sign test there are 29 chances of obtaining a result this favorable or more so in 128 trials; therefore the probability is P=.227. This value is certainly not statistically significant. In order to establish Professor Weber's conclusion (*f*), it would be necessary to obtain more data; and in doing so it would be advisable to take temperature readings at equal intervals of time.

(*g*) "During charge, and starting with discharged cells, treated cells gave higher hydrometric readings than did untreated cells, the differences being greater than could be explained on the basis of treating material added."

The data presented to substantiate this statement is enclosed in Table V where the differences tabulated are the excess of the treated cells over the untreated as follows:

TABLE V.—*Hydrometric Differences*

Pairs	Difference	
	November 5	November 6
43, 44*	55	100
45*, 46	60	55
47*, 48	90	Not Done
49, 50*	50	50
53*, 54	60	75
55*, 56	30	25
103A, 103B*	70	25

In the text Professor Weber noted that of these excesses about only 10 points could be associated with the addition of AD–X2 due to its own physical properties apart from its operation as a reagent. Therefore all of the magnitudes noted in the table are still definitely positive when any number in the neighborhood of 10 is subtracted from each, and a "t" test would show a significant increase. However, without making any hypothesis regarding the distribution, the probability of getting 7 positive differences on November 5th is $P=\frac{1}{128}$ which is highly significant. If one wished to include the data on November 6th as independent data (which would be erroneous, since some dependence is evident), $P=\frac{1}{8192}$. The true significance of this arrangement is somewhere between these two figures, and it is not worthwhile to try to take account of the dependence since the former value is already significant.

(*h*) "When AD–X2 was added to a cell containing a diluted electrolyte, as in a discharged cell, the conductivity of the electrolyte increased."

The observations were not taken in such a manner as to make a statistical analysis feasible under any hypothesis which seems to us defensible.

It may seem peculiar that with the significance we have found in many of these experiments showing that the effect of AD–X2 is real, we have not given any estimates of the possible effectiveness and limits within which we might expect these estimates to lie. There are two reasons for this. First, it seems to us that in order to make statements of that nature, it is essential to acquire considerably more knowledge of the form of the distributions of the behavior of batteries in general regarding the measured attributes. Second, we have no direct data on interbattery differences when AD–X2 is added to some batteries and not to others. Nevertheless, it has been established under the controlled conditions of this experiment that the addition of AD–X2 has changed on the average the performance of the individual cells as regards many of their attributes.

9. Statement of Supporting Scientific Authority

December 8, 1952.

Professor Harold C. Weber,
Massachusetts Institute of Technology.

Dear Professor Weber: During the first part of November 1952, I made, at the request of President Killian, some observations and a few experimental studies on the effect of a battery additive AD–X2 on lead acid storage batteries. The work was done in your laboratory, on storage cells selected by me from a group of batteries in your possession. In addition, I observed your work during this period.

The following statements are made concerning the report, "Some Facts Concerning the Effect of Battery Additive AD–X2 on Lead Acid Batteries," by Harold C. Weber and dated December 1, 1952.

1. *Sampling.*—In a laboratory test extending over a relatively short time, the cells used for testing must necessarily come from batteries that have been discarded or from batteries that have stood for a long time in a discharged state. The latter, although preferable, are usually not available. Discarded batteries have frequently developed mechanical defects to a greater or less extent in one or more cells. For this reason, valid conclusions cannot be drawn from the comparison of one complete battery against another unless a large number of samples are studied. A smaller number of samples would be required in the method used by you where a comparison is made between a treated and an untreated cell taken from the same battery. However, even in this method, many tests are necessary to determine the effect, beneficial or otherwise, of a battery additive. Definitive conclusions can only be drawn from laboratory test extending over long periods of time or from extensive field tests.

2. *Summary of Results.*—I observed the following facts concerning the results listed in your Paragraph 5.

(*a*) "Among the cells in any chosen battery, all cells in such battery having been subjected to the same previous history, except for treatment with AD–X2, treated cells showed larger capacities than did untreated cells, both being subjected to the same conditions of discharge."

In the experiments I made or observed, this was true except for two treated cells that would not take a charge. Both were found to have broken separators.

(*c*) "Cells treated with AD–X2 when on charge presented a markedly different appearance from those on charge without treatment. The gas evolved in the treated cells was in the form of minute bubbles, while that evolved in the untreated cells was in bubbles estimated to be 4 to 10 times as large as those evolved in the treated. The liquid surface in the treated cells presented a different appearance from that in the untreated cells."

This striking difference in behavior was observed in every cell I studied or observed. The gas evolved in the treated cells was in the form of bubbles so small that they did not always rise to the surface of the liquid immediately, but eddied around in the liquid in swirls that gradually rose. The surface of a treated cell during and after charge seemed to be partly covered with small specks that gave the surface an oily appearance.

(*d*) "The surface of a negative plate in a treated cell was distinctly softer than the surface of a similar plate in an untreated cell, both

having been subjected to the same charge conditions. Often, softening was first evident near the edges of the negative plate."

(*e*) "Under similar charge conditions, treated cells lost less liquid than untreated cells."

(*f*) "Under identical conditions of charge, treated cells operated 2 to 5 degrees Fahrenheit cooler than did untreated cells."

(*g*) "During charge, and starting with discharged cells, treated cells gave higher hydrometric readings than did untreated cells, the differences being greater than could be explained on the basis of the treating material added."

The statements in the above four paragraphs are in accordance with my observations except for the two treated cells, mentioned earlier, that had broken separators.

In conclusion, I would say that the addition of AD–X2 certainly does have an effect on the behavior of a lead acid battery. From my brief contact with the work, I cannot say that this effect is correlated with a beneficial action from the standpoint of the normal use of such a battery. I feel that the latter can be determined only after the examination and statistical evaluation of extensive field tests.

Very truly yours,

JAMES A. BEATTIE,
Professor of Physical Chemistry.

APPENDIX

Supporting Laboratory Data

These data are, with one exception, all that were collected in the laboratory tests made on AD–X2. They are here presented exactly as they appear in the laboratory notebooks, with the exception that data referring to a particular cell have been collected at one point, rather than having them arranged chronologically as they were recorded, irrespective of the particular cell being tested at any specified time. This rearrangement was followed merely to aid others in studying the data. The key to the arrangement originally practiced in the laboratory is found by referring to the dates on which the various experiments were performed. The one exception was a small amount of data collected in a preliminary way by Dr. Beattie personally to familiarize himself with the experimental techniques employed.

Data for the first 10 cells were previously reported briefly at a conference at the Bureau of Standards on September 29, 1952.

Charging of Cells 1, 2, and 3

Time	Charge Rate	CELL NO. 1 Temp.	Grav.	Volt	CELL NO. 2 Temp.	Grav.	Volt	CELL NO. 3 Temp.	Grav.	Volt
Sept. 16, 1952										
10:25 (1)	½ amp.	24	1100		24	1100		24	1100	
11:50	½ amp.	24	1100		24	1100		24	1100	
1:30	.75 amp.	25		2.9	25	1100	2.5	25	1100	2.9
1:40					AD–X2 added					
1:45	1 amp.			2.6			2.1			2.6
2:45	2 amp	26.5	1100	2.8	26.5	1100	2.4	26.5	1100	2.7
3:50	3.1 "	29.0	1100	2.7	29.0	1100	2.4	29.0	1100	2.6
Charged 5 hrs. 25 min.										
Sept. 18, 1952										
11:00	Not Charging	23	1100	.8	23	1100	.8	23	1100	.8
11:05	1 amp.	23	1100	3.1	23	1100	2.1	23	1100	3.1
11:40	2.5 "	25	1100	2.7	25	1100	2.4	25	1100	2.7
11:55	3.0 "	26	1100	2.7	26	1100	2.5	26	1100	2.7
1:35	4.5 "	32	1100	2.4	34	1100	2.4	32	1100	2.4
3:45	5.5 "	34		2.3	37		2.3	35		2.3
3:50	Charge stopped			1.9			1.9			1.9
Charged 4 hrs. 50 min. Room temp. Sept. 16, 24 Sept. 18, 23										

DISCHARGE

	Volt.	Amp.	Time	Volt.	Amp.	Time	Volt.	Amp.	Time
Sept. 18, 1952									
	1.9	5	4:01	1.2	5	4:15	1.6	5	4:17
	1.6		4:02	1.0		4:16	1.6		4:18
	1.5		4:06				1.5		4:19
	1.4		4:07	Cell evidently shorted			1.4		4:21
	1.3		4:10				1.3		4:22
	1.2		4:11				1.0		4:25
	1.0		4:12						
		11 min.						8 min.	

1. Original liquid in cell and water added to cover plates.
2. Cells 1 and 3 evolving large bubbles freely. No bubbles from Cell 2. Liquid level in Cells 1 and 3 raised about ¼″.
3. Cells 1 and 3 evolving gas freely. Cell 2—no gas evolution.

4. In cell 2, hydrometer floats but reading less than 1100. Some white deposit showing on edges of plates Cell 2.

These cells constructed by sawing apart a single navy standard cell to make four small units. Three units used. Cells assembled in lucite case with open air insulation spaces between cells. Lead strips burned on the cells for connections.

These cells supplied with new separators and assembled into plastic jar used previously. Acid of 1100-gravity added. Cell 2 treated with AD–X2 before start of charging.

Cell 1 was from center of original cell and not as badly sulphated as were Cells 2 and 3. This conclusion based on visual observation.

Note these three cells were originally on charge 9/16/52 for 9 hrs. 10 min. with a short in Cell 2. This led to conclusion to install new separators. All cells were discharged, new separators installed, 1100-gravity acid added, Cell 2 treated with AD–X2, and then all three placed on charge as indicated. Note Cells 1 and 3 now have an unfair advantage over Cell 2 because of extra 9 hr. 10 min. to break sulphate—and this extra charging was carried on in (essentially) a water electrolyte—not an acid one.

Charged Cells 1, 2, and 3

		CELL NO. 1			CELL NO. 2			CELL NO. 3		
Time	Charge Rate	Temp.	Grav.	Volt.	Temp.	Grav.	Volt.	Temp.	Grav.	Volt.
Sept. 23, 1952										
4:45	4.5	25	1100	2.4	25	1100	2.5	25	1100	2.4
5:55	4.5	25	1100	2.4	26	1100	2.4	26	1100	2.4
	Charging discontinued over-night									
Sept. 24, 1952										
11:00	0	20.2	1100	1.9	20.2	1100	1.9	21.0	1100	1.9
11:02	5 amp.									
3:00	Charging stopped									

Discharge Cells 1, 2, and 3

CELL NO. 1		
Open Circuit Volt 2.1		
Time	Amp.	Volt.
3:13	10	1.9
3:15	10	1.8
3:16	10	1.8
3:18	10	1.8
3:20	10	1.8
3:22	10	1.8
3:24	10	1.8
3:26	10	1.8
3:28	10	1.8
3:30	10	1.8
3:32	10	1.8
3:34	10	1.7
3:37	10	1.7
3:40	10	1.7
3:42	10	1.7
3:44	10	1.7
3:46	10	1.6
3:48	10	1.5
3:49	10	1.3
3:49½	10	1.0
36.5 min.		

CELL NO. 2		
Open Circuit Volt 2		
Time	Amp.	Volt.
3:52	10	1.8
3:55	10	1.8
3:57	10	1.8
4:00	10	1.7
4:05	10	1.7
4:10	10	1.7
4:15	10	1.7
4:20	10	1.5
4:21	10	1.5
4:22	10	1.4
4:23	10	1.3
4:24	10	1.2
4:25	10	1.0
33 min.		

CELL NO. 3		
Open Circuit Volt 2		
Time	Amp.	Volt.
4:26	10	1.8
4:35	10	1.8
4:40	10	1.8
4:45	10	1.7
4:50	10	1.6
4:51	10	1.3
4:52	10	1.0
26 min.		

SEPTEMBER 25, 1952.

Recovery test on cells 1, 2, and 3. These cells previously discharged September 24, 1952, and have stood 19 hours without additional charging.

Cell 2 has AD–X2

Open Circuit Voltage—Cell 1, 1.9; Cell 2, 1.9; Cell 3, 1.9

CELL NO. 1			CELL NO. 2			CELL NO. 3		
Time	Amp.	Volts	Time	Amp.	Volts	Time	Amp.	Volts
11:36	5	1.8	12:00	5	1.8	12:30	5	1.7
11:37		1.8	12:01		1.8	12:31		1.7
11:38		1.8	12:02		1.8	12:32		1.7
11:39		1.8	12:03		1.8	12:33		1.7
11:40		1.8	12:04		1.8	12:34		1.7
11:41		1.8	12:05		1.8	12:35		1.7
11:42		1.8	12:06		1.8	12:36		1.7
11:43		1.8	12:07		1.8	12:37		1.7
11:44		1.7	12:08		1.8	12:38		1.7
11:45		1.7	12:09		1.7	12:39		1.7
11:46		1.7	12:10		1.7	12:40		1.6
11:47		1.7	12:11		1.7	12:41		1.6
11:48		1.7	12:12		1.7	12:42		1.6
11:49		1.7	12:13		1.7	12:43		1.6
11:50		1.7	12:14		1.7	12:44		1.6
11:51		1.7	12:15		1.7	12:45		1.6
11:52		1.6	12:16		1.7	12:46		1.5
11:53		1.6	12:17		1.6	12:47		1.4
11:54		1.6	12:18		1.6	12:48		1.3
11:55		1.5	12:19		1.5	12:49		1.0
11:56		1.3	12:20		1.4		19 min.	
11:57		1.2	12:21		1.4			
11:58		1.0	12:22		1.3			
	22 min.		12:24		1.2			
			12:25		1.2			
			12:26		1.1			
			12:26½		1			
				26½ min.				

All three cells appear to be in excellent condition by observation.

At 12:50 dead shorted all cells to eliminate inequalities in recuperation. Put on charge at 12:55 at 5 amp.

SEPTEMBER 25, 1952.

Discharge of Cells 1, 2, and 3 After Charging Till 3:30
(2 hrs. 35 minutes at 5 amp.)

Open Circuit Voltage—Cell 1, 2 volts; Cell 2, 2 volts; Cell 3, 2 volts

CELL NO. 1			CELL NO. 2			CELL NO. 3		
Time	Amp.	Volt	Time	Amp.	Volt	Time	Amp.	Volt
3:50	10	1.9	4:38	10	1.7	5:25	10	1.8
3:52		1.9	4:40		1.7	5:35		1.8
3:55		1.9	4:45		1.7	5:50		1.8
4:00		1.8	4:50		1.7	5:55		1.7
4:05		1.8	4:55		1.7	6:00		1.6
4:15		1.8	5:00		1.7	6:01		1.5
4:16		1.7	5:05		1.7	6:02		1.3
4:20		1.7	5:10		1.6	6:03		1.2
4:22		1.7	5:15		1.6	6:03½		1.0
4:25		1.7	5:17		1.5		38½ min.	
4:30		1.6	5:20		1.4			
4:32		1.5	5:21		1.3			
4:33		1.4	5:22		1.2			
4:34		1.2	5:23		1.1			
4:34½		1.0	5:24¼		1			
	44½ min.			46¼ min.				

Note concerning Cell 2: Lug which had been burned on positive plate bank broke off near end of charge period. Could have been a bad connection during previous tests on this cell. Substitute a needlepoint connection for broken lug since no other means of connection was immediately available.

Charged Cells 4 and 5

Cells were Exide Hycap Cells from junk battery with heavily sulphated plates. New separators installed. Cells assembled in original case with center compartment empty. This was Group II battery.

1100 acid added. Cells stood over night. Gravity dropped on standing over night. Temperature cannot be read—cannot get thermometer into cell. Gravity on Cell 5 practically 1100.

Sept. 19, 1952

Time	Charge Rate	CELL NO. 4 Temp.	Grav.	Volt	CELL NO. 5 Temp.	Grav.	Volt
9:23	5 amp.					AD-X2 added	
9:26			1100	3.0		1100	2.0
10:00				2.6			2.1
11:00			1100	2.5		1100	2.2
12:00		32.3	1100	2.4	29.2	1100	2.1
1:00		33.2	1100	2.3	29.7	1100	2.1
2:20		33.8	1100	2.2	29.8	1100	2.1

Charged 4 hrs. 57 min.

DISCHARGE

Time	Amp.	Volt
3:33	—	1.8
3:34	6	1.4
3:36		1.3
3:38		1.1
3:39		1

6 min.

Time	Amp.	Volt
2:34	—	2
2:35	6	1.9
2:40		1.9
2:50		1.9
3:00		1.9
3:10		1.9
3:20		1.8
3:26		1.7
3:29		1.4
3:30		1.3
3:32		1.0

55 min.

Tests on recovery of cells 4 and 5 previously discharged after standing 96 hours with no recharging.

CELL NO. 4 No AD-X2 Time	Amp.	Volt
11:30	—	1
11:30	.5	0

CELL NO. 5 AD-X2 added Time	Amp.	Volt
11:31	—	1.9
11:32	4	1.9
11:33		1.8
11:34		1.8
11:35		1.8
11:36		1.8
11:37		1.8
11:38		1.8
11:39		1.8
11:40		1.8
11:41		1.8
11:42		1.8
11:43		1.7
11:44		1.7
11:45		1.7
11:46		1.7
11:47		1.7
11:48		1.7
11:49		1.6
11:50		1.6
11:51		1.4
11:52		1.3
11:53		1.3
11:54		1.2
11:55		1.0

24 min.

Second discharge without recharging on cells 4 and 5 after standing 1 hr. 40 min. Cell 4 showed open circuit voltage of 1.0 and .3 volts at .2 amp.

CELL NO. 5

Time	Amp.	Volt
1:35	4	1.8
1:36		1.8
1:37		1.8
1:38		1.8
1:39		1.8
1:40		1.8
1:41		1.7
1:42		1.7
1:43		1.7
1:44		1.6
1:45		1.6
1:46		1.3
1:47		1.3
1:48		1.2
1:49		1.0

14 min.

SEPTEMBER 26, 1952.

Cells 4 and 5 were put on charge at 10:55 at 7 amps. and charged for one hour. They had previously been discharged on September 24, 1952.

CELL NO. 4

Open Circuit Volt. 1.8

Time	Amp.	Volt.
1:10	5	1.5
1:11		1.4
1:12		1.4
1:13		1.3
1:14		1.3
1:15		1.1
1:15½		1.0

3½ min.

CELL NO. 5

Open Circuit Volt. 2.0

Time	Amp.	Volt.
1:20	5	1.9
1:21		1.9
1:22		1.9
1:23		1.9
1:24		1.9
1:25		1.9
1:26		1.9
1:27		1.9
1:28		1.9
1:29		1.9
1:30		1.8
1:31		1.8
1:32		1.8
1:33		1.8
1:34		1.8
1:35		1.8
1:36		1.8
1:37		1.8
1:38		1.8
1:39		1.8
1:40		1.8
1:41		1.8
1:42		1.8
1:43		1.8
1:44		1.8
1:45		1.8
1:46		1.8
1:47		1.8
1:48		1.8
1:49		1.8
1:50		1.8
1:51		1.8
1:52		1.8
1:53		1.8
2:00		1.8
2:05		1.8
2:10		1.8
2:15		1.8
2:20		1.8
2:25		1.8
2:30		1.8
2:34		1.7
2:35		1.6
2:36		1.4
2:37		1.3
2:39		1.3
2:40		1.2
2:40¾		1.0

80¾ min.

NOTE: Cell 4 went almost as long at 5 amp. discharge after 1 hr. charge as it went previously at 6 amp. discharge after previous 5-hr. charge.

NOTE: Cells 4 and 5 stood from 9/24/52 at 1:30 P. M. till 10:55 P. M. on 9/26/52 when they were put on charge at 7 amp. for one hour.

SEPTEMBER 26, 1952.

Additional Experiments on Sulphated Untreated Cell No. 4

Cell put on charge at 2:42 p. m. at 7 amps. AD–X2 added and charged at 7 amps. till 3:40 p. m. (58 min.).

Discharge on Cell No. 4

Open Circuit Voltage 1.8

Time	Amp.	Volt.
5:05	5	1.5
5:06		1.5
5:07		1.4
5:08		1.4
5:09		1.3
5:10		1.2
5:11		1.2
5:12		1.1
5:13¼		1.0

8¼ min.

NOTE: When this Cell without AD–X2 was previously discharged after 58 min. charge at 7 amp., it went only 5½ min., as contrasted with 8¼ min. this time.

SEPTEMBER 22, 1952.

Two Autolite Cells from Group I passenger car battery. New wood separators installed, cells drained and 1100 acid added. Separators were soaked in water. Gravity at start under 1100 but hydrometer floated.

Evidence of shorting band of sulphate on both ends of Cell 7.

Cells assembled in outside sections of 3-section glass container.

Loose sulphate mud removed from between edges of plates on Cell 7 with filter paper. Same treatment given to Cell 6, although no shorting mud was in evidence. Thermometer checked and read same at same temperature.

Charged cells 6 and 7, 3 hours 20 min. at 5 amps.

Cells 6 and 7

		CELL NO. 6			CELL NO. 7		
Time	Charge Rate	Temp.	Grav.	Volt.	Temp.	Grav.	Volt.
11:40	—	24.0	1100—	1.6	24.0	1100—	1.1
11:44	4 amp.			3.4			3.3
11:46	5 amp.			3.2			3.2
11:48	5 amp.					AD–X2 Added	
11:55	5 amp.			2.8			2.7
1:54	5 amp.	27.0	1100—	2.5	28.5	1100—	2.6
3:00	5 amp.	27.8	1100—		28.9	1100—	—*

*Room Temp. 23

DISCHARGE

	CELL NO. 6			CELL NO. 7		
	Time	Amp.	Volt.	Time	Amp.	Volt.
	3:21	5	1.7	3:05	5	1.8
	3:22	5	1.7	3:07	5	1.7
Before discharge, open circuit voltage was 1.9 on both cells.	3:25	5	1.5	3:10	5	1.6
	3:29	5	1.0	3:15	5	1.4
		8 Min.		3:17	5	1.2
				3:20	5	1.0
					15 Min.	

SEPTEMBER 23, 1952.

Cells 6 and 7

CHARGE

Time	Charge Rate	CELL NO. 6 Temp.	CELL NO. 6 Grav.	CELL NO. 6 Volt.	CELL NO. 7 Temp.	CELL NO. 7 Grav.	CELL NO. 7 Volt.
3:45	—	27.0	1100–	1.6	26.8	1100–	1.8
3:47	5 amp.	27.0	1100–	2.3	26.8	1100–	2.4
4:15	7 amp.		1100–	2.3		1100–	2.4
4:35	7 amp.	28.2	1100–	2.3	27.2	1100–	2.4
5:00	7 amp.	29.0	1100–	2.3	27.5	1100–	2.4

DISCHARGE

CELL NO. 6 Time	CELL NO. 6 Amp.	CELL NO. 6 Volt.	CELL NO. 7 Time	CELL NO. 7 Amp.	CELL NO. 7 Volt.
5:01	5	1.9	5:21	5	1.8
5:05	5	1.8	5:25	5	1.8
5:10	5	1.7	5:30	5	1.7
5:14	5	1.6	5:34	5	1.7
5:16	5	1.5	5:40	5	1.6
5:17	5	1.3	5:41	5	1.5
5:18	5	1.2	5:43	5	1.4
5:20	5	1.1	5:45	5	1.3
5:21	5	1.0	5:47	5	1.2
	20 Min.		5:48	5	1.1
			5:51	5	1.0
				30 Min.	

Before discharge, open circuit voltage was 2.0 on both cells.

SEPTEMBER 24, 1952.

Cells 6 and 7

Tests on recovery of Cells 6 and 7 previously discharged after standing 17 hours without recharging.

CELL NO. 6 No AD-X2 Time	CELL NO. 6 No AD-X2 Amp.	CELL NO. 6 No AD-X2 Volt.	CELL NO. 7 AD-X2 Added Time	CELL NO. 7 AD-X2 Added Amp.	CELL NO. 7 AD-X2 Added Volt.
11:05	—	1.6	11:08	—	1.9
11:06	4	.7	11:09	4	1.7
11:07	3	.5	11:11	4	1.6
			11:12	4	1.5
			11:13	4	1.5
			11:14	4	1.4
			11:15	4	1.4
			11:16	4	1.3
			11:17	4	1.3
			11:18	4	1.2
			11:19	4	1.1
			11:20	4	1.0x
				12 Min.	

Second discharge without recharging on Cells 6 and 7 after standing 1 hr. 30 min.

CELL NO. 6 DEAD	CELL NO. 7 Time	CELL NO. 7 Amp.	CELL NO. 7 Volt.
	1:53	4	1.6
	1:54	4	1.4
	1:55	4	1.4
	1:56	4	1.3
	1:57	4	1.3
	1:58	4	1.2
	1:59	4	1.1
	2:00	4	1.0x
		7 Min.	

SEPTEMBER 26, 1952.

Discharge of Cells 6 and 7

Cells 6 and 7 put on charge at 10:55 at 7 amps. and charged for 1 hr. They were previously discharged on September 24, 1952.

CELL NO. 6		
Open Circuit Volt. 1.8		
Time	Amp.	Volt.
4:02	5	1.7
4:03		1.6
4:04		1.4
4:05		1.3
4:06		1.1
4:06½		1.0
4½ min.		

CELL NO. 7		
Open Circuit Volt. 1.9		
Time	Amp.	Volt.
4:08	5	1.9
4:10		1.9
4:15		1.8
4:30		1.7
4:35		1.7
4:40		1.7
4:45		1.7
4:50		1.6
4:55		1.5
4:56		1.4
4:57		1.4
4:58		1.4
4:59		1.3
5:00		1.2
5:01		1.1
5:02		1.1
5:03¾		1.0
55¾ min.		

NOTE: Cells 6 and 7 stood from 5:21 p. m. on 9/23/52 till 2:40 on 9/26/52 when they were put on charge at 7 amp. till 3:40 p. m.

SEPTEMBER 24, 1952.

EFFECT OF AD–X2 ON GRAVITY

An Autolite high level group one cell required 550 cc. of liquid to bring level to a height such as to cover plates and plate lugs.

When 1 envelope of AD–X2 was added to 550 cc. of 1135 acid, the gravity rose to 1155.

SEPTEMBER 25, 1952.

To 550 cc. of 1300 acid in a graduate 1 envelope of AD–X2 was added. Acid was at approximately room temperature. Gravity rose to 1320.

Tests on New "Beacon" 13 Plate 90 A. H. Battery From Fresh Stock Made by Gould National

Cell No.	8	9	10
Sp. Gr.	1250	1250	1250
Temp.	22	22	22

Battery put on charge at 4 amp. at 10:50. AD–X2 added to Cell 10 at 10:55. Immediately after adding AD–X2, hydrometer reading was 1260. Note less gravity rise than when no elements are present.

After charging for 3 hrs. 17 min. whole battery was discharged starting at 2:07 at rate of 25 amp. At 5 P. M. battery would no longer light a single 21 C. P. bulb.

SEPTEMBER 26, 1952.

Visual inspection of plates in Cells 4, 5, 6, 7 at end of experiments showed negatives softer on treated cells than on untreated, even though hard sulphation had not been completely cleaned up.

SEPTEMBER 26, 1952.

Discharge on Cells 8, 9, 10 After Complete Discharge on September 25, 1952 and Standing Over Night

CELL NO. 9

Open Circuit Volt. 2.0

Time	Amp.	Volt.
11:30	10	1.9
11:31		1.9
11:32		1.9
11:33		1.9
11:34		1.9
11:35		1.9
11:36		1.9
11:37		1.9
11:38		1.9
11:39		1.8
11:40		1.8
11:41		1.8
11:42		1.7
11:43		1.7
11:44		1.7
11:45		1.7
11:46		1.6
11:47		1.4
11:47¾		.8

17¾ Min.

CELL NO. 10

Open Circuit Volt. 2.0

Time	Amp.	Volt.
11:50	10	1.8
11:52		1.8
11:53		1.8
11:54		1.8
11:55		1.8
11:56		1.8
11:57		1.8
11:58		1.8
11:59		1.8
12:00		1.8
12:01		1.8
12:02		1.8
12:03		1.8
12:04		1.8
12:05		1.7
12:06		1.6
12:07		1.4
12:07¾		.9

17¾ Min.

CELL NO. 8

Open Circuit Volt. 1.6

Time	Amp.	Volt.

Would not take 10 amp. load. Shorted.

NOTE that this battery, although fresh and charged starting at 1250 gr. for 3 hr. 17 min. at 4 amp. went only 2 hr. 53 min. at 25 amp. discharge indicating a defect.

OCTOBER 14, 1952.

Cells 11, 12, 13, and 14

These were four of six cells in a 12 V US2HM–11 Plate Willard airplane battery (probably 40 A. H.) obtained from salvage at Fort Devens. One end cell was removed for examination. It showed some sulphation and generally was in good condition. Cell between first two and fourth and fifth left empty and bridged for isolation purposes.

First two and fourth and fifth cells filled with 1100 acid.

Battery placed on charge for 10 minutes at 5 amps. After 10 minutes all cells showed 1.8 V open circuit. Cells immediately discharged.

Discharge Data

CELL NO. 11

Time	Amp.	Volt.
4:03	10	1.7
4:04		1.7
4:05		1.6
4:06		1.5
4:07		1.4
4:07:5		1.3
4:07:08		1.0

4 min., 8 sec.

CELL NO. 12

Time	Amp.	Volt.
4:09	10	1.7
4:10		1.6
4:11		1.6
4:12		1.6
4:13		1.55
4:14		1.5
4:15		1.5
4:16		1.2
4:16:30		1.0

7 min. 30 sec.

CELL NO. 13

Time	Amp.	Volt.
5:17	10	1.65
5:18		1.65
5:19		1.60
5:20		1.55
5:21		1.50
5:22		1.50
5:23		1.4
5:24		1.0

7 minutes

CELL NO. 14

Time	Amp.	Volt.
4:25	10	1.60
4:26		1.60
4:27		1.55
4:28		1.50
4:29		1.50
4:30		1.50
4:31		1.4
4:32		1.0

7 minutes

OCTOBER 15, 1952.

Cells 11 and 12 treated with AD–X2. Battery put on charge at 5 amp. from 4:40 to 5:35 and all cells discharged to 1 amp. on short circuit. Battery allowed to stand in discharged condition till October 20.

No gravities or temperatures taken since charge period was too short to affect them.

OCTOBER 20, 1952.

Cells 11, 12, 13, and 14

Discharge After Recovery From October 15 to October 20

CELL NO. 11

Time	Amp.	Volt.
2:30	5	1.65
2:31	5	1.65
2:32	5	1.65
2:33	5	1.65
2:34	5	1.60
2:35	10	1.60
2:36		1.60
2:37		1.60
2:38		1.60
2:39		1.60
2:40		1.55
2:41		1.55
2:44		1.55
2:45		1.50
2:47		1.50
2:48		1.45
2:49		1.35
2:50		1.2
2:51		1.1
2:51:15		1.0

21 min. 15 sec.

CELL NO. 13

Time	Amp.	Volt.
3:09	5	1.8
3:10	5	1.7
3:11	5	1.7
3:12	5	1.7
3:13	5	1.7
3:15	10	1.7
3:20		1.7
3:22		1.7
3:24		1.65
3:26		1.6
3:27		1.6
3:28		1.5
3:29		1.2
3:29:30		1.0

20 min. 30 sec.

CELL NO. 12

Time	Amp.	Volt.
3:31	5	1.8
3:32	5	1.8
3:33	5	1.8
3:34	5	1.8
3:35	5	1.8
3:36	10	1.75
3:38		1.75
3:40		1.75
3:42		1.75
3:44		1.75
3:46		1.75
3:48		1.75
3:50		1.70
3:51		1.65
3:53		1.65
3:54		1.60
3:55		1.55
3:56		1.5
3:57		1.3
3:58		1.2
3:58:45		1.0

27 min. 45 sec.

CELL NO. 14

Time	Amp.	Volt.
4:01	5	1.8
4:02	5	1.75
4:03	5	1.75
4:04	5	1.75
4:05	5	1.75
4:06	15	1.7
4:08		1.7
4:10		1.7
4:12		1.7
4:14		1.7
4:16		1.7
4:18		1.65
4:19		1.6
4:20		1.5
4:20:45		1.0

19 min. 45 sec.

OCTOBER 20, 1952.

Cells 11, 12, 13, and 14

Second Discharge After Standing From Times Given on Page 2—No Recharging

CELL NO. 11

Time	Amp.	Volt.
4:24	5	1.75
4:25		1.70
4:26		1.70
4:27		1.70
4:28		1.70
4:29		1.70
4:30		1.70
4:31		1.70
4:32		1.70
4:33		1.65
4:34		1.65
4:35		1.60
4:36		1.60
4:37		1.60
4:38		1.60
4:39		1.60
4:40		1.60
4:41		1.60
4:42		1.60
4:43		1.50
4:44		1.50
4:45		1.40
4:46		1.30
4:47		1.20
4:48		1.0

24 minutes

CELL NO. 13

Time	Amp.	Volt.
4:49	5	1.8
4:50		1.8
4:51		1.75
4:52		1.75
4:53		1.75
4:54		1.75
4:55		1.75
4:56		1.75
4:57		1.65
4:58		1.65
4:59		1.65
5:00		1.65
5:01		1.65
5:02		1.65
5:03		1.65
5:04		1.65
5:05		1.55
5:06		1.3
5:06:48		1.0

17 min. 48 sec.

CELL NO. 12

Time	Amp.	Volt.
5:08	5	1.85
5:09		1.75
5:10		1.75
5:11		1.75
5:12		1.75
5:13		1.75
5:14		1.75
5:15		1.75
5:16		1.75
5:17		1.75
5:18		1.75
5:19		1.75
5:20		1.7
5:21		1.7
5:22		1.7
5:23		1.7
5:24		1.7
5:25		1.7
5:26		1.65
5:27		1.65
5:28		1.60
5:29		1.55
5:30		1.5
5:31		1.4
5:32		1.3
5:33		1.25
5:34		1.20
5:34:45		1.0

26 min. 45 sec.

CELL NO. 14

Time	Amp.	Volt.
5:39	5	1.8
5:40		1.8
5:41		1.8
5:42		1.75
5:43		1.75
5:45		1.75
5:46		1.75
5:47		1.75
5:48		1.75
5:49		1.75
5:50		1.75
5:51		1.75
5:52		1.75
5:53		1.75
5:54		1.70
5:55		1.70
5:56		1.70
5:57		1.70
5:58		1.65
5:59		1.65
6:00		1.60
6:01		1.55
6:02		1.2
6:02:48		1.0

23 min. 48 sec.

OCTOBER 21, 1952.

Cells 15 and 16

These were two cells from a standard automobile battery supposed sulphated. Third cell was removed, plates were in good condition and showed sulphation. Battery was a Mobile Delux 51 plate 120 A. H. Group II. Cells charged at 5 amp. for 15 min.

Discharge Data

CELL NO. 15

Time	Amp.	Volt.
4:32	5	1.7
4:33		1.7
4:34		1.7
4:35		1.7
4:36		1.7
4:37		1.7
4:38		1.6
4:39		1.6
4:39:30		1.0

7 min. 30 sec.

CELL NO. 16

Time	Amp.	Volt.
5:42	5	1.7
5:43		1.7
5:44		1.7
5:45		1.7
5:46		1.6
5:47		1.6
5:48		1.6
5:49		1.6
5:50		1.5
5:50:15		1.0

8 min. 15 sec.

OPEN CIRCUIT VOLTAGE

Cell 15	1.8
Cell 16	1.8

OCTOBER 22, 1952.

Cells put on charge at 2:41 at 5 amps. AD–X2 added to Cell 15 at 2:48. Cells taken off charge at 3:45.

Discharge Data

CELL NO. 15

Time	Amp.	Volt.
4:00	15	1.75
4:01		1.80
4:02		1.75
4:03		1.75
4:04		1.75
4:05		1.75
4:06		1.75
4:07		1.75
4:08		1.7
4:09		1.6
4:09:30		1.0

9 min. 30 sec.

CELL NO. 16

Time	Amp.	Volt.
4:11	15	1.80
4:12		1.75
4:13		1.75
4:14		1.75
4:15		1.75
4:16		1.75
4:17		1.75
4:18		1.75
4:19		1.75
4:20		1.7
4:21		1.6
4:21:20		1.0

10 min. 20 sec.

OPEN CIRCUIT VOLTAGE

Cell 15	1.95
Cell 16	1.90

OCTOBER 23, 1952.

Cells 15 and 16

Cells recharged at 5½ Amps. from 8:45 to 11:45.

Discharge Data

CELL NO. 15

Time	Amp.	Volt.
2:44	51	1.7
2:45	51.6	1.75
2:46	52.5	1.75
2:47	52.7	1.80
2:48	52.5	1.75
2:49	52.5	1.70
2:50	52.5	1.70
2:51	51.6	1.65
2:52	51.2	1.60
2:53	49.4	1.50
2:54	45.7	1.45
2:55	36.2	1.0

11 min.

CELL NO. 16

Time	Amp.	Volt.
2:53	54	1.7
2:54	54	1.7
2:55	54	1.7
2:56	54	1.7
2:57	53.2	1.65
2:58	53.2	1.65
2:59	52.5	1.65
3:00	51.2	1.6
3:01	51	1.55
3:02	48.7	1.50
3:03	41.9	1.2
3:03:30	34.4	1.0

10 min. 30 sec.

OPEN CIRCUIT VOLT.

Cell 15	1.95
Cell 16	1.95

Variable discharge rate because of difficulty with rheostat

OCTOBER 23, 1952.

Cells 15 and 16

These cells placed on charge at 4:15 at 5 amps.

OCTOBER 24, 1952.

Cells 15 and 16

Off charge at 2:45. However, these cells did not charge overnight. Clip fell off during night.

Gravity Reading

Cell No.	15	16
Gravity	11. 50	11. 50

These cells placed on charge again at 9:10 and taken off at 6:25.

OCTOBER 28, 1952.

Cells 15 and 16

CELL NO. 15		
Time	Amp.	Volt.
3:48	40	1. 75
3:56		1. 75
4:00		1. 75
4:10		1. 75
4:12		1. 70
4:15		1. 70
4:20		1. 70
4:25		1. 65
4:30		1. 60
4:32		1. 50
4:33		1. 40
4:33:30		1. 2
4:35		1. 0
47 min.		

CELL NO. 16		
Time	Amp.	Volt.
3:00	40	1. 75
3:01		1. 75
3:02		1. 75
3:06		1. 75
3:10		1. 75
3:15		1. 75
3:20		1. 75
3:25		1. 75
3:27		1. 65
3:30		1. 65
3:35		1. 65
3:40		1. 65
3:42		1. 55
3:44		1. 50
3:45		1. 40
3:45:15		1. 30
3:45:30		1. 10
3:45:50		1. 00
45 min. 50 sec.		

NOTE: Cell 16 was discharged before Cell 15 as recorded.

OCTOBER 30, 1952.

Cells 15 and 16 placed on charge at 4 amp. at 11:25.
Cells 15 and 16 taken off charge at 2:40.

OCTOBER 31, 1952.

Discharge Data—Cells 15 and 16

CELL NO. 15		
Time	Amp.	Volt.
12:50	40	1. 55
12:51		1. 55
12:53		1. 55
12:54		1. 55
12:55		1. 55
12:57		1. 55
1:00		1. 55
1:02		1. 50
1:04		1. 50
1:05		1. 50
1:07		1. 45
1:10		1. 35
1:11		1. 00
21 min.		

CELL NO. 16		
Time	Amp.	Volt.
1:15	40	1. 75
1:17		1. 75
1:18		1. 75
1:20		1. 75
1:25		1. 75
1:27		1. 70
1:31		1. 65
1:32		1. 65
1:35		1. 60
1:37		1. 50
1:38		1. 40
1:39		1. 20
1:39:10		1. 00
24 min. 10 sec.		

OCTOBER 23, 1952.

Cells 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, and 28

These are two type U. S. 2HN–11 Plate airplane batteries made by Willard and obtained from salvage from Fort Devens at same time as were Cells 11–12–13–14. All cells dry as received—filled with 1100 acid. All cells placed on charge at 5 amps. at 2:27.

Discharge Data

CELL NO. 17

Time	Amp.	Volt.
3:36	30	1.75
3:37	30	1.75
3:37:30	18	1.0

CELL NO. 19

Time	Amp.	Volt.
3:44	30	1.65
3:45	30	1.65
3:46	30	1.55
3:47	29	1.5
3:48	23	1.1
3:48:20	18	1.10

CELL NO. 21

Time	Amp.	Volt.
3:52	30	1.3
3:53	30	1.1
3:53:10	30	1.0

OPEN CIRCUIT VOLT.

Cell	Volt.
17	2
18	1.9
19	2
20	1.9
21	1.8
22	1.8
23	1.9
24	1.6
25	0.3
26	1.45
27	0.05
28	1.3

CELL NO. 18

3:38	30	1.6
3:39	29	1.5
3:40	29	1.5
3:41	28	1.5
3:42	25	1.3
3:42:30	23	1.0

CELL NO. 20

3:49	30	1.6
3:49:45	24	1.0

CELL NO. 22

3:55	30	1.4
3:55:45	29	1.0

OCTOBER 23, 1952.

Cells Nos. 17–18–19–20–21–22–23–24–25–26–27–28

CELL NO. 23

Time	Amp.	Volt.
3:58	30	1.4
3:59	30	1.1
3:59:15	30	1.0

CELL 24	DEAD
CELL 25	DEAD
CELL 26	DEAD
CELL 27	DEAD
CELL 28	DEAD

Following cells treated with AD–X2:

Cells Nos. 20–22–24–26–28

All cells placed on charge at 4 amps. at 4:15 p. m. All gravities at close of charge under 1100—float just about floats.

OCTOBER 24, 1952.

Cells Nos. 17–18–19–20–21–22–23–24–25–26

Taken off charge at 10:10. Impossible to get reading of temperatures during charging because could not get thermometer bulb immersed through filler hole.

Gravity Readings at 2:30

CELL NO.	17	18	19	20	21	22	23	24	25	26	27	28
Gravity	1160	1140	1175	1220	1145	1175	1200	1235	1200	1225	1200	1200

OCTOBER 24, 1952.

Cells 17 to 28

Discharge Data

CELL NO. 17

Time	Amp.	Volt.
3:11	30	1.7
3:12		1.7
3:15		1.7
3:17		1.7
3:19		1.7
3:20		1.7
3:25		1.65
3:29		1.5
3:29:45		1.0

18 min. 45 sec.

CELL NO. 18

Time	Amp.	Volt.
3:31	30	1.75
3:32		1.75
3:35		1.75
3:39		1.75
3:40		1.75
3:45		1.75

Terminal Broke

CELL NO. 19

Time	Amp.	Volt.
4:10	30	1.85
4:15		1.85
4:20		1.85
4:22		1.85
4:25		1.80
4:30		1.80
4:32		1.80
4:35		1.80
4:40		1.75
4:45		1.65
4:46		1.60
4:47:30		1.0

37 min. 30 sec.

CELL NO. 20

Time	Amp.	Volt.
4:51	30	1.9
4:55		1.85
5:00		1.85
5:05		1.75
5:10		1.70
5:12		1.60
5:13		1.30
5:14:45		1.00

23 min. 45 sec.

CELL NO. 21

Time	Amp.	Volt.
5:16	30	1.8
5:17		1.8
5:19		1.8
5:25		1.8
5:30		1.8
5:35		1.75
5:36		1.70
5:38		1.70
5:40		1.65
5:42		1.65
5:44		1.60
5:45		1.40
5:45:30		1.0

29 min. 30 sec.

CELL NO. 22

Time	Amp.	Volt.
5:47	30	1.85
5:49		1.80
5:55		1.75
5:60		1.75
6:05		1.70
6:10		1.70
6:15		1.60
6:17		1.5
6:18		1.4
6:20		1.0

33 min

OCTOBER 27, 1952.

Cells 23 to 28

Discharge After Standing Since October 24 at 2:30

CELL NO. 23

Time	Amp.	Volt.
3:34	40	1.8
3:35		1.8
3:40		1.8
3:45		1.75
3:47		1.70
3:50		1.65
3:53		1.60
3:55		1.60
3:56		1.55
3:58		1.50
3:59		1.40
3:59:15		1.20
3:59:30		1.00

25 min. 30 sec.

CELL NO. 24

Time	Amp.	Volt.
4:01	40	1.8
4:05		1.8
4:10		1.8
4:13		1.75
4:15		1.75
4:17		1.70
4:19		1.65
4:20		1.60
4:21		1.50
4:22		1.20
4:22:15		1.00

21 min. 15 sec.

CELL NO. 25

Time	Amp.	Volt.
4:30	40	1.8
4:32		1.8
4:35		1.8
3:40		1.75
3:41		1.70
3:44		1.60
3:45		1.50
3:45:15		1.40
3:45:30		1.30
3:45:45		1.20
3:46		1.00

16 min.

OPEN CIRCUIT VOLT.

Cell	Volt.
23	2.0
24	2.0
25	2.0
26	2.1
27	2.0
28	2.1

CELL NO. 26

Time	Amp.	Volt.
11:29	40	1.8
11:30		1.85
11:35		1.80
11:36		1.75
11:40		1.75
11:44		1.65
11:45		1.60
11:46		1.55
11:46:30		1.50
11:47		1.40
11:47:30		1.30
11:48		1.1
11:48:15		1.0

19 min. 15 sec.

CELL NO. 27

Time	Amp.	Volt.
1:30	40	1.75
1:34		1.65
1:35		1.65
1:40		1.60
1:42		1.50
1:43		1.40
1:43:30		1.30
1:43:45		1.20
1:41:20		1.00

14 min. 20 sec.

CELL NO. 28

Time	Amp.	Volt.
1:46	40	1.85
1:50		1.85
1:55		1.75
1:58		1.70
2:00		1.70
2:02		1.65
2:05		1.60
2:07		1.55
2:10		1.50
2:11		1.40
2:12		1.20
2:12:15		1.10
2:12:30		1.00

26 min. 30 sec.

NOTE.—Then these cells discharged about eighteen hours after Cells 23, 24, 25.

NOTE.—Sulphated cells probably do not hold charge till after sulphate is completely broken.

OCTOBER 27, 1952.

Cells 29 and 30

These are two cells from a Willard heavy duty 115 AH 6-volt automobile battery, group 2, 17 plates per cell. Third cell cracked. This battery obtained from Mr. Goodwin. Battery had stood with electrolyte in it for 2½ years. Charged from 3:16 to 4:41 at 5 amps. Cell 30 treated with AD–X2.

OCTOBER 28, 1952.

Cells 29 and 30

CELL NO. 29			CELL NO. 30		
Time	Amp.	Volt.	Time	Amp.	Volt.
2:36	60		2:38:15	75	1.7
Died immediately			2:38:45		1.1

OCTOBER 30, 1952.

Discharge Data, Cells 29 and 30

Cells 29 and 30 on charge at 6 amps. 2:45 P. M. taken off 5:55.

CELL NO. 29			CELL NO. 30		
Time	Amp.	Volt.	Time	Amp.	Volt.
11:42	10	1.65	2:07	10	1.70
11:43		1.65	2:08		1.70
11:50		1.65	2:10		1.70
11:55		1.60	2:15		1.70
12:00		1.55	2:20		1.70
12:10		1.55	2:25		1.70
12:15		1.55	2:30		1.70
12:20		1.55	2:35		1.70
12:25		1.50	2:40		1.70
12:26		1.40	2:45		1.65
12:27		1.20	2:50		1.65
12:28:30		1.10	2:55		1.65
12:28		1.00	3:00		1.65
46 min. 30 sec.			3:05		1.65
			3:07		1.60
			3:10		1.60
			3:12		1.55
			3:15		1.55
			3:18		1.50
			3:20		1.40
			3:22:15		1.15
			3:22		1.00
			75 min. 15 sec.		

OCTOBER 27, 1952.

Cells Nos. 31, 32, 33, 34

These cells from Exide radio battery brought to Boston by Ritchie on October 27. Cells were dry—elements only brought—no case. Battery was dated on strap sixth month of 1942. These four cells made from two larger cells. In this process one positive from each of the larger cells was discarded.

Cells were placed in distilled water and assembled into a plastic airplane case made for six cells. Two center compartments were left empty for insulation. New separators were installed in all cells. Then cells put on charge at 4.5 amps at 2:43 and taken off at 4:50. Cells 31 and 32 treated with AD–X2.

Voltages

CELLS	31	32	33	34
Immediately after treatment	4.4	4.4	4.1	4.1
Five minutes after treatment	2.9	2.9	4.8	4.7
At 2:54	3.1	3.1	3.8	3.8
At 3:21	2.9	2.9	2.8	2.7

Thermometers were inserted in all cells. Thermometers were checked for agreement before using.

Treated cells during charge ran about 2° C. cooler than untreated cells (28° versus 30°). After charge had stopped treated cells rose 1° to 2° above untreated cells. Treated cells showed heavier and more lasting froth than untreated cells.

OCTOBER 28, 1952.

Voltages, Open Circuit

CELL	31	32	33	34
Voltage	1.20	1.20	1.45	1.40
Temp.	24	24	25	25

On Charge at 5 amp. at 2:20.

CELL	31	32	33	34
Voltage	2.90	2.90	4.25	4.00

OCTOBER 28, 1952.

Cells 31, 32, 33, 34

Charging

CELL	31	32	33	34
Voltage	3.0	3.0	3.8	3.40
Time	2:25	2:25	2:25	2:25
Temperature	25	24	27	26
Time	2:32	2:32	2:32	2:32
Temperature	26	25	28	28
Voltage	2.80	2.80	2.90	2.85
Time	2:45	2:45	2:46	2:46
Temperature	28	27	30	30
Voltage	2.60	2.60	2.80	2.80

At 2:55 treated cells were evolving large amounts of fine pin point bubbles. Untreated cells were evolving larger bubbles.

CELL	31	32	33	34
Time	3:22	3:22	3:23	3:23
Temperature	32	31	31	30
Voltage	2.40	2.40	2.60	2.60

Above temperatures may have been influenced by presence of light to observe fine bubble formation.

Charging—Continued

CELL	31	32	33	34
Time	4:57	4:57	4:58	4:58
Temperature	35	34	34	34
Voltage	2. 40	2. 40	2. 35	2. 35

Cells taken off charge 5:00.

OCTOBER 28, 1952.

Cells 31, 32, 33, and 34

Discharge Data

CELL NO. 31

Time	Amp.	Volt.
5:05	10	1.7
5:07	10	1.65
5:09	10	1.60
5:10	10	1.55
5:11	10	1.55
5:12	10	1.50
5:13	10	1.50
5:14	10	1.40
5:15	10	1.40
5:17	10	1.40
5:18	10	1.30
5:19	10	1.20
5:19	10	1.10
5:19	10	1.10

14 min. 50 sec.

CELL NO. 33

Time	Amp.	Volt.
5:22	10	1.6
5:23	10	1.55
5:24	10	1.50
5:25	10	1.50
5:26	10	1.50
5:28	10	1.40
5:28	10	1.10
5:28	10	1.10

6 min. 35 sec.

OPEN CIRCUIT VOLTAGE

Cell #31 Volt. 1.8

Cell #32 Volt.

Cell #33 Volt.

Cell #34 Volt.

CELL NO. 32

Time	Amp.	Volt.
5:33	10	1.65
5:34	10	1.60
5:35	10	1.60
5:36	10	1.55
5:37	10	1.55
5:38	10	1.50
5:39	10	1.50
5:40	10	1.50
5:41	10	1.50
5:42	10	1.50
5:43	10	1.45
5:43	10	1.40
5:44	10	1.35
5:45	10	1.30
5:46	10	1.10
5:46	10	1.00

13 min. 45 sec.

CELL NO. 34

Time	Amp.	Volt.
5:48	10	1.55
5:49	10	1.55
5:50	10	1.50
5:51	10	1.50
5:52	10	1.4
5:53	10	1.4
5:53	10	1.1
5:54		1.0

6 min. 1 sec.

OCTOBER 30, 1952.

Cells 31, 32, 33, and 34, although starting with equal liquid levels, required the following amounts of water to again make levels equal: Cell 31, none; Cell 32, none; Cell 33, 22 c. c.; Cell 34, 31 c. c.

OCTOBER 31, 1952.

Cells Nos. 31, 32, 33, 34

Each cell killed individually.

Water added to each cell to bring level to mark put on transparent case.

Hydrometer will not float in any cell.

On charge at 12:40 at 6 amp.

Cell No.	31	32	33	34	Time
Voltage	2.35	2.30	2.40	2.40	12:43
Voltage	2.21	2.21	2.19	2.19	1:16
Gravity	Float just floats		Float doesn't float		2:31
Temperature	30.8	30.8	31.6	32	2:50
Voltage	2.25	2.25	2.20	2.20	5:31
Gravity	Same as above				
Temperature	34	35	35	36	5:30

Above cells off charge at 5:40.

NOVEMBER 3, 1952.

Discharge on Cells Nos. 31, 32, 33, 34

CELL NO. 31		
Time	Amp.	Volt.
3:20	20	1.75
3:22		1.70
3:31		1.60
3:37		1.55
3:40		1.50
3:41		1.45
3:42		1.40
3:43		1.30
3:44		1.20
3:44:10		1.10
3:44:15		1.00
24 min. 15 sec.		

CELL NO. 33		
Time	Amp.	Volt.
3:46	20	1.75
3:47		1.70
3:48		1.65
3:49		1.60
3:50		1.60
3:55		1.55
3:56		1.50
4:01		1.45
4:05		1.45
4:07		1.30
4:08		1.10
4:08:10		1.00
22 min. 10 sec.		

NOVEMBER 3, 1952.

Charge Data

Cell No.	31	32	33	34	Time	
Voltage	1.8	1.8	1.8	1.8	9:25	Open circuit.
Voltage	2.25	2.25	2.20	2.20	9:38	On charge at 5 amp.
Voltage	2.30	2.30	2.26	2.26	11:27	On charge.
Voltage	2.30	2.31	2.26	2.24	12:55	On charge.

Suntester Voltmeter checked against Hoyt voltmeter:

	Sun meter 2.30		Hoyt meter 2.35			
Gravity	1100	1100	Less than 1100			
Voltage	2.28	2.29	2.26	2.25	2:10	
Temperature	33	33	34	34	2:30	Off charge.

NOVEMBER 3, 1952.

Discharge Data

CELL NO. 32			CELL NO. 34		
Time	Amp.	Volt.	Time	Amp.	Volt.
4:10	20	1.70	4:34	20	1.75
4:10		1.70	4:36		1.70
4:13		1.65	4:40		1.70
4:16		1.65	4:45		1.65
4:20		1.60	4:46		1.60
4:25		1.60	4:48		1.60
4:28		1.55	4:50		1.55
4:30		1.50	4:51		1.50
4:31		1.45	4:52		1.40
4:31:30		1.30	4:52:15		1.80
4:32		1.20	4:52:25		1.20
4:32:30		1.10	4:52:30		1.1
4:32:45		1.00	4:52:40		1.0
22 min. 45 sec.			18 min. 40 sec.		

OPEN CIRCUIT VOLTAGE

Cell 31 Voltage 2.1
Cell 32 Voltage 2.0
Cell 34 Voltage 2.0

NOTE: Above cells have received considerable charging and since they are probably about 30 amp. hour units probably have recovered to a considerable degree. Also note gravity cannot be expected to rise very high even on full charge since cells were at start filled with distilled water, and moreover, cells contain much free volume for excess liquid, thus tending to result in a low gravity.

NOVEMBER 4, 1952.

Discharge After Standing All Night and After Discharge

CELL NO. 31			CELL NO. 33		
Time	Amp.	Volt.	Time	Amp.	Volt
11:33	5	1.8	4:24:30	5	1.8
11:38		1.75	4:37		1.75
12:05		1.70	4:50		1.70
12:15		1.65	4:57		1.65
12:30		1.60	5:06		1.65
12:44		1.5	5:24		1.55
12:47		1.4	5:34		1.50
12:49		1.25	5:38		1.4
12:50		1.2	5:39		1.3
12:52		1.1	5:41		1.1
12:53		1.05	5:43		1.0
12:53:30		1.			
77 min. 30 sec.			78 min 30 sec.		

OCTOBER 29, 1952.

Cells 35, 36, 37, 38, 39, and 40

These are Sunoco type 112E acquired October 29th.
Cells 35, 36, 37, strap dated November 1947.
Cells 38, 39, 40, strap dated February 1948.
Cells contained residue of original electrolyte.
Liquid level adjusted by adding distilled water.
All six cells on charge at 5 amp. at 1:55 P. M.—off at 2:55.
New separators were installed in all cells.

Discharge after 1 hour charge at 5 amp.

CELL 35	CELL 36	CELL 37			CELL 38	CELL 39	CELL 40
Dead	Dead	Time	Amp.	Volt.	Dead	Dead	Dead
		4:25	3.75	1.4			
		4:27	3.75	1.2			
		4:28	3.75	1.1			
		4:29:30		1.0			
		4 min. 30 sec.					

After discharge cells 36, 38, 40 were treated with AD–X2. Note that apparent best cell #37 was not treated.

All six cells on charge at 4:55 P. M. at 5 amp.

Voltage readings on charge at 5 amp.

	CELL 35	CELL 36	CELL 37	CELL 38	CELL 39	CELL 40
Time			VOLTAGES			
5:25	2.80	2.60	2.20	2.55	2.35	2.45
5:13	2.50	2.35	2.05	2.45	2.30	2.40
6:00	2.50	2.28	2.01	2.30	2.29	2.21

Off charge at 6:00 P. M.

OCTOBER 30, 1952.

At 10:30 checked cells 35, 36, 37, and 38, 39, 40 for shorts between cells with 110 volt test lamp. Cells 35 and 36 are shorted. On ohmmeter resistance is under 60 ohm. Resistance between 36 and 37 is under 2000 ohm. Others show several thousand ohms between cells and no glow on test lamp.

Cells 37, 38, 39, 40 on charge at 11:25 at 4 amp.

OCTOBER 31, 1952.

Discharge on Cells 37, 38, 39, and 40

CELL NO. 37			
Time	Amp.	Volt.	
1:45	40	1.55	
1:46		1.55	Cells 38, 39, 40 were dead
1:47		1.50	in spite of fact that they
1:48		1.45	were charged in series with
1:49		1.35	Cell 37.
1:50		1.20	
1:50:30		1.00	
5 min. 30 sec.			

OCTOBER 30, 1952.

Cells 41, 42, 43, 44, 45, 46

These were put on charge at 11:45.

These are two cell batteries made by removing center cell from Sunoco 112E type batteries obtained by Goodwin and Ritchie on October 29th. These cells filled with enough distilled water to bring level up. Cells 41 and 42 have original separators. Cells 43, 44, 45, 46 have original wood separators. Cells off charge at 12:15.

OCTOBER 31, 1952.

Cells 41 through 56 put on charge (with 6 unnumbered cells for Dr. Beattie) at 2:45. Can get less than 1 amp. through bank. Off charge at 3:45. Every cell was dead. At 4:05 following cells were treated 42, 47, 55, 53, 52, and put on charge at 5 amp. Off charge at 5:30.

Reading	Cell	41	42	43	44	45	46	47	48	49	50
TAKEN	Temp. °C.	38*	33*	—	—	—	—	32	36	—	—
5:10 to	Gravity	NR	NR	—	—	—	—	NR	NR	—	—
5:15	Volt.*	2.90	2.60	—	—	—	—	2.60	2.90	—	—

* Voltages with 6 amp. charging current.

Cell	51	52	53	54	55	56
Temp. °C.	28*	29*	27	32	34	35
Gravity	NR	NR	NR	NR	NR	NR
Voltage*	2.20	2.35	2.10	3.00	3.00	2.90

*Voltages with 6 amp. charging current.
*Approximately.
— Not on charge.
NR Too low to read.

NOVEMBER 3, 1952.

Cells 41–42, 47–48, 51–52, 53–54, 55–56

These cells previously on charge at 5 amp. for 1 hour 25 minutes.
Again placed on charge at 2 amp. at 9:15.
Charge rate up to 4.5 amp. at 9:30.

CELL	41	42	47	48	51	52	53	54	55	56	Time
On Charge Volt.	4.01	3.02	2.90	3.78	2.30	2.52	2.05	3.50	3.48	3.52	9:15
On Charge Volt.	2.32	2.25	2.20	2.40	2.20	2.30	2.18	2.40	2.41	2.39	12:55

Discharge

CELL NO. 47

Time	Amp.	Volt.
1:00	40	1.2
1:00		1.0

CELL NO. 48

Time	Amp.	Volt.
Not up to 40 amp. Dead		

CELL NO. 41

Time	Amp.	Volt.
Not up to 40 amp. Dead		

CELL NO. 42

Time	Amp.	Volt.
Not up to 40 amp. Dead		

CELL 51

Time	Amp.	Volt.
1:05	10	1.60
1:07		1.60
1:09		1.60
1:10		1.55
1:12		1.50
1:14		1.40
1:15		1.30
1:16		1.10
1:16:30		1.00
11 min. 30 sec.		

CELL 52

Time	Amp.	Volt.
1:20	10	1.65
1:21		1.65
1:22		1.60
1:23		1.55
1:24		1.50
1:25		1.45
1:26		1.40
1:28		1.10
1:28:45		1.00
8 min. 45 sec.		

CELL 55

Time	Amp.	Volt.
1:30	10	1.65
1:31		1.50
1:31:15		1.40
1:31:30		1.30
1:32		1.10
1:32:05		1.00
2 min. 5 sec.		

CELL 56

Time	Amp.	Volt.
1:35:30	10	1.50
1:36:30		1.00
1 min.		

Sulphate on Cell 52 soft.
Sulphate on Cell 51 hard.

Cells 41, 42, 47, 48, back on charge at 5 amp. at 1:30.

Discharge

CELL NO. 53

Time	Amp.	Volt.
1:45	10	1.65
1:46		1.65
1:48		1.65
1:50		1.65
1:55		1.65
2:00		1.60
2:04		1.55
2:05		1.50
2:07		1.50
2:10		1.40
2:11		1.35
2:12		1.25
2:13		1.26
2:14		1.15
2:15		1.05
2:15:30		

30 min. 30 sec.

CELL NO. 54

Time	Amp.	Volt.
2:18	10	1.10
2:18:30		1.00

30 sec.

Sulphate on Cell No. 53 soft.
Sulphate on Cell No. 54 hard.

NOVEMBER 3, 1952.

Cells 44, 45, 50 treated at 3:30.
Cells 41–42, 43–44, 45–46, 49–50, 51–52, 53–54, 55–56.
Also 101A, 101B, 102A, 102B, 103A, 103B for Dr. Beattie placed on charge at 3:40.

NOVEMBER 4, 1952.

Discharge

CELL NO. 53

Time	Amp.	Volt.
2:30	20	1.75
2:32		1.65
2:35		1.65
2:40		1.60
2:42		1.55
2:44		1.55
2:45		1.40
2:46		1.30
2:47		1.25
2:48		1.10
2:49		1.05
2:49:50		1.00

19 min. 50 sec.

CELL NO. 54

Time	Amp.	Volt.
2:57		1.15
2:58:40		1.00

1 min. 40 sec.

CELL NO. 41

Dead. "Sulphated out."

CELL NO. 42

Not run because it was dead.

CELL NO. 55

Time	Amp.	Volt.
3:20	20	1.10
3:20:10		1.00

10 sec.

CELL NO. 56

Time	Amp.	Volt.
3:23	20	1.10
3:23:20		1.00

20 sec.

CELL NO. 53

Time	Amp.	Volt.
3:24	20	1.50
3:25		1.50
3:26		1.40
3:27		1.30
3:28		1.20
3:28:55		1.00

4 min. 55 sec.

CELL NO. 54

Time	Amp.	Volt.
3:30	20	1.2
3:30:30		1.0

30 sec.

Cells 41 and 42 discarded because 41 "sulphated out" on trying to charge it.

NOVEMBER 4, 1952.

Cells 45 and 46

Discharge Data

CELL NO. 45

Time	Amp.	Volt.
3:32	20	——
	Dead	

CELL NO. 46

Time	Amp.	Volt.
3:33	20	——
	Dead	

CELL NO. 49

Time	Amp.	Volt.
3:34	20	——
	Dead	

CELL NO. 50

Time	Amp.	Volt.
	Dead	

CELL NO. 43

Dead

CELL NO. 44

Dead

CELL NO. 51

Time	Amp.	Volt.
3:28	20	1.60
3:42		1.55
3:43		1.45
3:44		1.40
3:45		1.10
3:45:15		1.00
7 min. 15 sec.		

CELL NO. 52

Time	Amp.	Volt
3:47	20	1.50
3:48		1.50
3:50		1.40
3:51		1.30
3:52		1.10
3:52:15		1.00
5 min. 15 sec.		

CELL NO. 47

Time	Amp.	Volt.
4:07	20	1.65
4:10		1.60
4:11		1.60
4:13		1.55
4:14		1.50
4:15		1.40
4:16		1.40
4:17		1.20
4:18		1.20
4:19		1.05
4:20		1.00
13 min.		

CELL NO. 48

Time	Amp.	Volt.
4:22		
	Dead	

Cells 41–42, 43–44, 45–46, 49–50, 51–52, 53–54, 55–56, on charge at 4:10 at 3.6 amps. Cell 47–48 on charge at 4:30.

All these cells off charge at 9:30 AM November 5th.

NOVEMBER 5, 1952.

Plates on 52 considerably softer near edges than on any part of 51 after charging all night.

NOVEMBER 5, 1952.

Cells 53 and 54 show slightly irridescent film as if oil were present. These two cells may be contaminated.

Cell 52—Examined plates on this cell and found 4 cracked positives.

Cell 51 has no cracked positives.

Cells 45 and 46 off charge at 1:30.

Discharge Data

CELL NO. 45		
Time	Amp.	Volt.
1:34	40	1.50
1:35		1.50
1:36		1.40
1:37		1.40
1:38		1.40
1:40		1.40
1:43		1.40
1:47		1.40
1:48		1.35
1:50		1.25
1:51		1.20
1:52		1.15
1:53		1.05
1:53:45		1.00
19 min. 45 sec.		

CELL NO. 46		
Time	Amp.	Volt.
1:55	40	1.35
1:56		1.35
1:57		1.30
1:58		1.25
1:59		1.20
2:00		1.15
2:01		1.15
2:02		1.10
2:03		1.05
2:04		1.00
9 min.		

103A and 103B off charge at 2:05.
53–54 off charge at 2:30.
43–44 off charge at 2:30.

NOVEMBER 5, 1952.

Hydrometer Readings Taken at 10:30

CELL	49	50	45	46	53	54	47	48	
Gravity	1050	1100	1110	1050	1110	1050	1140	1050	
Water Make Up	38	72	20	54	20	66	*	*	CC

CELL	44	43	55	56	103A	103B		
Gravity	1105	1050	1080	1050	1050	1120		
Water Make Up	18	100	68	92	122	88		CC

Gravities less than 1100 taken with additional hydrometer. 1.000–1.500 checked against two battery hydrometers being used.

*Cannot do because no reference level found in cell (ledge on case).

Cells 49, 50, 45, 46, 53, 54, 44, 43, 55, 56, 103A, 103B put on charge again at 11:10 at 6 amp.

Discharge Data

CELL NO. 47		
Time	Amp.	Volt.
11:17	40	1.60
11:20		1.60
11:22		1.60
11:27		1.55
11:30		1.50
11:35		1.50
11:37		1.45
11:38		1.40
11:39		1.35
11:40		1.35
11:42		1.30
11:43		1.20
11:44		1.10
11:45		1.00
28 Min.		

CELL NO. 48		
Time	Amp.	Volt.
11:59:30	40	1.45
12:01		1.40
12:02		1.30
12:03		1.25
12:04		1.10
12:04:30		1.10
5 Min.		

CELL NO. 49		
Time	Amp.	Volt.
1:05	40	1.60
1:07		1.55
1:08		1.50
1:10		1.40
1:11		1.35
1:12		1.15
1:12:10		1.00
7 Min. 10 Sec.		

Discharge Data—Continued

CELL NO. 50

Time	Amp.	Volt.
1:13	40	1.60
1:15		1.55
1:16		1.55
1:17		1.55
1:18		1.50
1:19		1.50
1:20		1.45
1:21		1.45
1:22		1.40
1:23		1.30
1:24		1.20
1:24:45		1.00

11 Min. 45 Sec.

11:55 Visual examination of cells 49, 50, 45, 46, 53, 54, 44, 43, 55, 56, 103A, 103B while under charge at 6 amp. show treated cells evolving characteristic small bubbles in case of all treated cells (with exception noted) and surface appeared more viscous. Could not clearly see difference in case of cells 53 and 54.

NOVEMBER 5, 1952.

Discharge Data

CELL NO. 53

Time	Amp.	Volt.
3:32	40	1.60
3:35		1.55
3:40		1.55
3:45		1.55
3:50		1.50
3:55		1.45
4:00		1.40
4:05		1.35
4:06		1.30
4:07		1.25
4:09		1.20
4:10		1.20
4:12		1.00

40 min.

CELL NO. 54

Time	Amp.	Volt.
4:14	40	1.60
4:15		1.50
4:18		1.50
4:20		1.40
4:21		1.30
4:22		1.20
4:22:25		1.00

8 min. 25 sec.

CELL NO. 43

Time	Amp.	Volt.
4:30	40	1.45
4:32		1.35
4:32:30		1.30
4:33		1.20
4:34		1.00

4 min.

CELL NO. 44

Time	Amp.	Volt.
4:34	40	1.60
4:36		1.50
4:40		1.50
4:43		1.40
4:45		1.30
4:45:30		1.20
4:46		1.10
4:46:30		1.00

12 min. 30 sec.

CELL NO. 56

Time	Amp.	Volt.
4:49	40	1.55
4:51		1.50
4:55		1.45
4:58		1.40
4:59:30		1.30
5:00		1.20
5:00:45		1.10
5:00:15		1.00

12 min. 15 sec.

CELL NO. 55

Time	Amp.	Volt.
5:02	40	1.65
5:05		1.65
5:06		1.65
5:07		1.60
5:10		1.60
5:11		1.50
5:15		1.40
5:17		1.20
5:18		1.15
5:18:20		1.00*

16 min. 20 sec.

Cells 55–56 off charge 4:45 p. m.

*NOTE on Cell 55.—During discharge a bad connection in voltmeter circuit was discovered on this cell. This discovery was made near end of discharge. After completion of discharge battery was still found not to be down to 1.00 Volt. with repaired connection. This battery would have gone longer than 16 min. 20 sec.

NOVEMBER 6, 1952.

Following cells on charge at 10:15 at 11 amps. (used two sides of charger for this). Water level in all cells brought exactly to ledge cast in case at start of charge.

CELL	49	50	45	46	53	54	47	48	Time
Gravity	1090	1130	1175	1120	1175	1100	No ledge		3:30
Water added, cc	44	Over ledge	12	38	Over ledge	42			5:00

CELL	44	43	55	56	103A	103B	Time
Gravity	1150	1050	1125	1100	1150	1175	3:40
Water added, cc	None	52	None	32	28	Over ledge	4:55

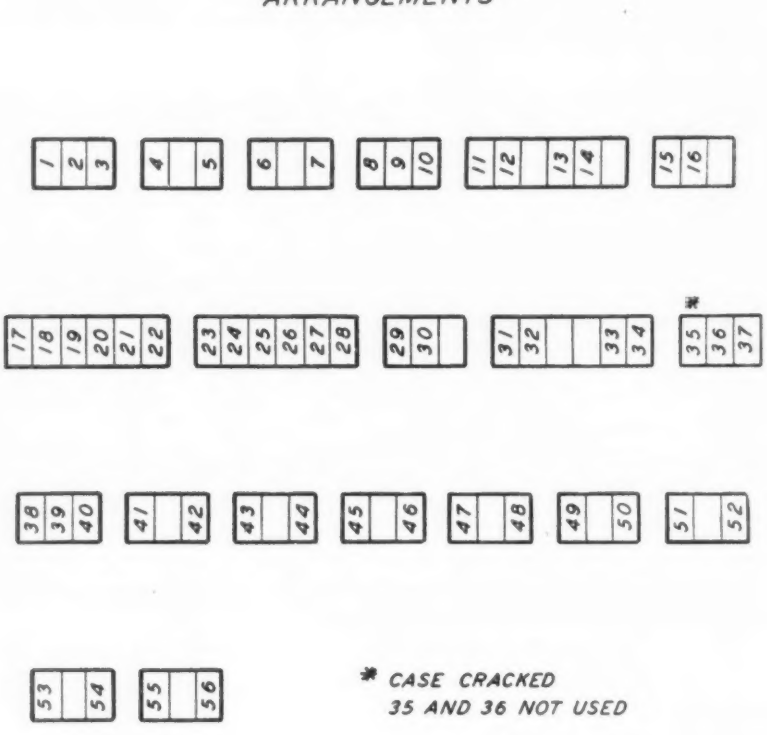
NOVEMBER 7, 1952.

At 10:20 again looked at water level in above cells. Level had dropped in several. Water level was once more brought up to reference ledge. Following amounts of water were necessary. Time 10:20–10:50 to do this.

CELL	49	50	45	46	53	54	47	48	44	43	55
CC Water	42	46	22	28	None		No ledge		26	22	34

CELL	56	103A	103B
CC Water	32	34	34

Above cells require approximately 800 cc. of electrolyte to bring level to ledge with plates in place in cell.



NOVEMBER 6–25.

GENERAL EXPERIMENTS OF LONG DURATION

1. DISAPPEARANCE OF SEDIMENT

A small, glass-cased Willard thick plate cell, approximately 15 years old, had been left in an uncharged condition for several years. Well over an inch of sediment had collected in the bottom of the cell, and the liquid level had fallen over 2 inches below the tops of the plates. Distilled water was added to restore the level. Battery AD–X2 was added to the cell, and the unit placed on charge at 3 amperes. In several hours sediment reduction was evident, and by the time the cell was fully charged, the sediment was less than ¼ inch deep in the cell bottom. This occurred in May 1952. During the present series of tests, this cell was again examined, and it was evident to those present and also present when the cell was originally charged after treatment, that sediment has shown a further considerable decrease. The cell has not been recharged.

Two groups of two cells each, of heavy plate Exide batteries (two plates per cell), were observed in the summer of 1952 at the Army Base in Boston. It was said that before treatment with AD–X2, these cells contained so much sediment that it was above the bottom of the plates, and some cells were being partially shorted by the sediment. The cells were treated about January 1952. When observed in July, the sediment had receded about ½ inch below the bottoms of the plates. The cells were moved to Cambridge in September, where they could be more readily observed. Sediment in one pair of cells is now approximately 1⅛ inches below the plate bottoms, while in the other pair, it is about 1 inch below the plates. On November 6 at 1:30, the second pair was placed on charge at 4 amp. until 5 p. m. On succeeding days for one week, it was alternately charged and discharged. From marks placed on the glass cases, a reduction of about ⅛ inch in sediment depth has been noted, some of this occurring while the cells were sitting idle for several days after the charge-discharge cycle. Complete sediment disappearance is not expected in these cells, but the level has receded to a point where difficulty from sediment is a remote possibility.

A record is made at this time of an automobile battery in a rubber case. A hole was accidentally knocked in the side of the case by a stone thrown up from the road. Although the battery was eighteen months old and had been treated with AD–X2 six months previously, no sediment was found in the cell bottom. Incidentally, the exposed negative plate was soft and apparently in excellent condition.

2. SOFTNESS OF TREATED NEGATIVES

Repeatedly, the relative hardness of outside negative plates was determined by ploughing the thumbnail across the treated and untreated negatives. Access to the plates was obtained by lifting the complete cell from the container just at the end of a charging period. The treated negatives were found to yield a soft, mushy quantity of paste by this procedure, while untreated negatives were hard, if sulfated, and yielded no such ploughed-up material. Sometimes the soft spots were found only at the plate edges of the treated negatives.

○